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HEAVY METALS IN CLASTIC STREAM SEDIMENTS OF THE YAKOUN RIVER DRAINAGE AND OTHER B.C. STREAMS

Regional Program Report No. 84-05

By

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ABSTRACT

A monitoring program was conducted to assess sediment heavy metal levels in the Yakoun River and tributary streams adjacent to a proposed gold mine property. Several other British Columbia streams were also sampled to establish a data base to compare to. Intergravel fine sediments from clastic stream beds typical of salmon spawning areas were effectively sampled with a stainless steel syringe sampler. Barbie Creek which drains the area surrounding the mine property had the highest overall mean mercury and arsenic concentrations compared to the other streams sampled by the syringe method. The results indicate that both seasonal differences and sampler methodology are important considerations when establishing baseline heavy metal sediment levels.

RÉSUMÉ

Un programme de surveillance a été mis en place pour permettre d'évaluer les niveaux de concentration des métaux lourds dans les sédiments de la rivière Yakoun et de ses affluents, cours d'eau qui ont pour caractéristique de longer des terrains aurifères proposés à l'exploitation.

En même temps on a prélevé des échantillons de sédiments dans d'autres cours d'eau de la Colombie-Britannique afin d'établir une base de données à laquelle se référer. À l'aide d'une seringue d'échantillonnage en acier inoxydable, on a ainsi prélevé des échantillons de sédiments fins à gravier dans le lit clastique de cours d'eau où le saumon abonde. C'est dans la rivière Barbie, cours d'eau qui draine la zone contiguë aux terrains aurifères qu'on a relevé les degrés de concentration moyenne de mercure et d'arsenic les plus élevés, en comparaison avec les autres cours d'eau dans lesquels on a aussi prélevé des échantillons à la seringue d'échantillonnage. Les résultats ont montré qu'il faut largement tenir compte à la fois des variations saisonnières et de la méthode d'échantillonnage lorsque l'on veut établir les niveaux de concentration de base des métaux lourds présents dans les sédiments.

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SUMMARY AND CONCLUSIONS

Clastic stream sediments typical of salmon spawning grounds were effectively sampled with a stainless steel syringe sampler. Barbie Creek which drains the proposed Cinola gold mine property had the highest overall mean sediment mercury (0.47 ug/g) and arsenic (63 ug/g) levels of the British Columbia streams sampled with the syringe sampler. The highest mean zinc (164 ug/g) concentration was measured at Lemieux Creek and the highest mean copper (86 ug/g) concentration was measured at Quinsam River.

Mercury and arsenic concentrations measured at station Barbie-3 by two methods (freeze core, syringe) were significantly different. Samples were obtained from the same area of creek bed and the < 150 um sediment fraction was used in both cases. The reason for this variability is not known but indicates consideration has to be given to sample methods when documenting baseline metal levels from which to evaluate post-operational impacts. There was no indication either sampler had mercury or arsenic contamination problems.

An element of seasonal variability existed between samples collected at stations in September 1982 and again in February 1983. For mercury, significant differences were detected at Barbie Creek stations B1 and B3 and Canoe Creek station C1. Seasonal variability is a consideration that has to be taken into account when documenting baseline metal levels from which to evaluate post-operational impacts.

1 INTRODUCTION

In July, 1980 Consolidated Cinola Mines Ltd., submitted a Stage I report to the Provincial Steering Committee for Development of New Metal Mines (Fanning and Griffing, 1980). The report summarized that the ore, waste rock, soils and tailings may contain anomalously high levels of mercury and other heavy metals. The Cinola project is located on Graham Island (Queen Charlotte Islands) and was identified as having a potential for impacting upon the anadromous fishery resources of the Yakoun River drainage.

As part of a pre-development data collection program the Environmental Protection Service (Department of Environment) undertook a monitoring program in September 1982 and February 1983 to assess the heavy metal levels in clastic stream sediments adjacent to the proposed mine development. In addition, sediment samples were collected from other B.C. streams in 1983 to provide a data base to compare to. This report presents the data collected over 1982 and 1983.

2 DESCRIPTION OF STUDY AREA

The Yakoun River drains an area of approximately 477 km^2. The Yakoun River flows in a northerly direction and drains into Masset Inlet near Port Clements (Figure 1). Tributary streams of the Yakoun River that have been identified as having a possibility of being influenced by the Cinola project include Canoe Creek, Florence Creek and Barbie Creek (Figures 1 and 2).

Other rivers and streams that were sampled in B.C. include: Myra Creek, Quinsam River and Cowichan River on Vancouver Island; Pinchi, Foxy and Lemieux Creeks in Central B.C.; Salmon and Seymour Rivers in the Lower Mainland and the Mamin River on Graham Island (Figure 3).

A description of each station is provided in Appendix I.

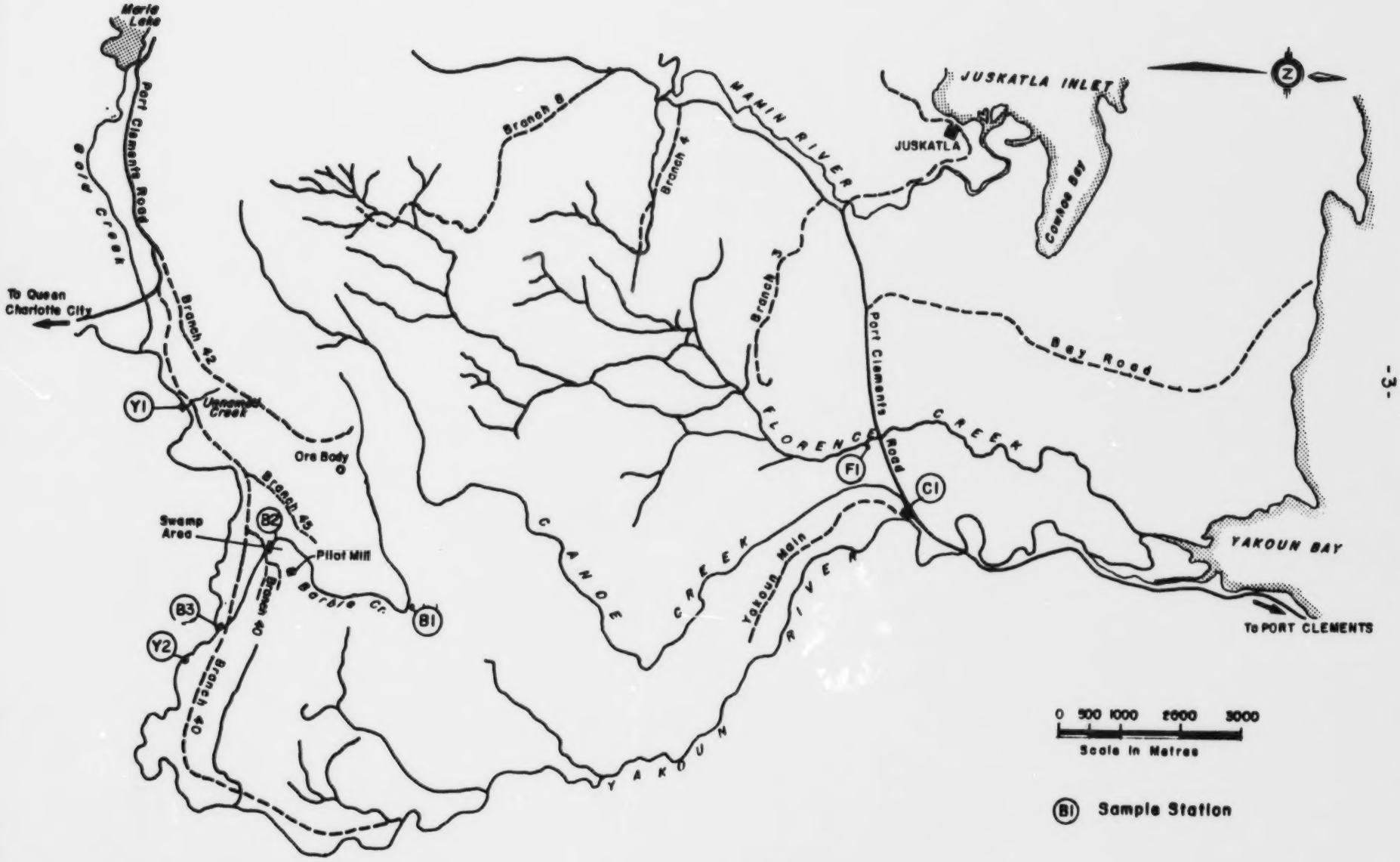

FIGURE 1 YAKOUN RIVER AND SEDIMENT SAMPLE STATION LOCATIONS

FIGURE 2 BARBIE CREEK SAMPLE STATION LOCATIONS

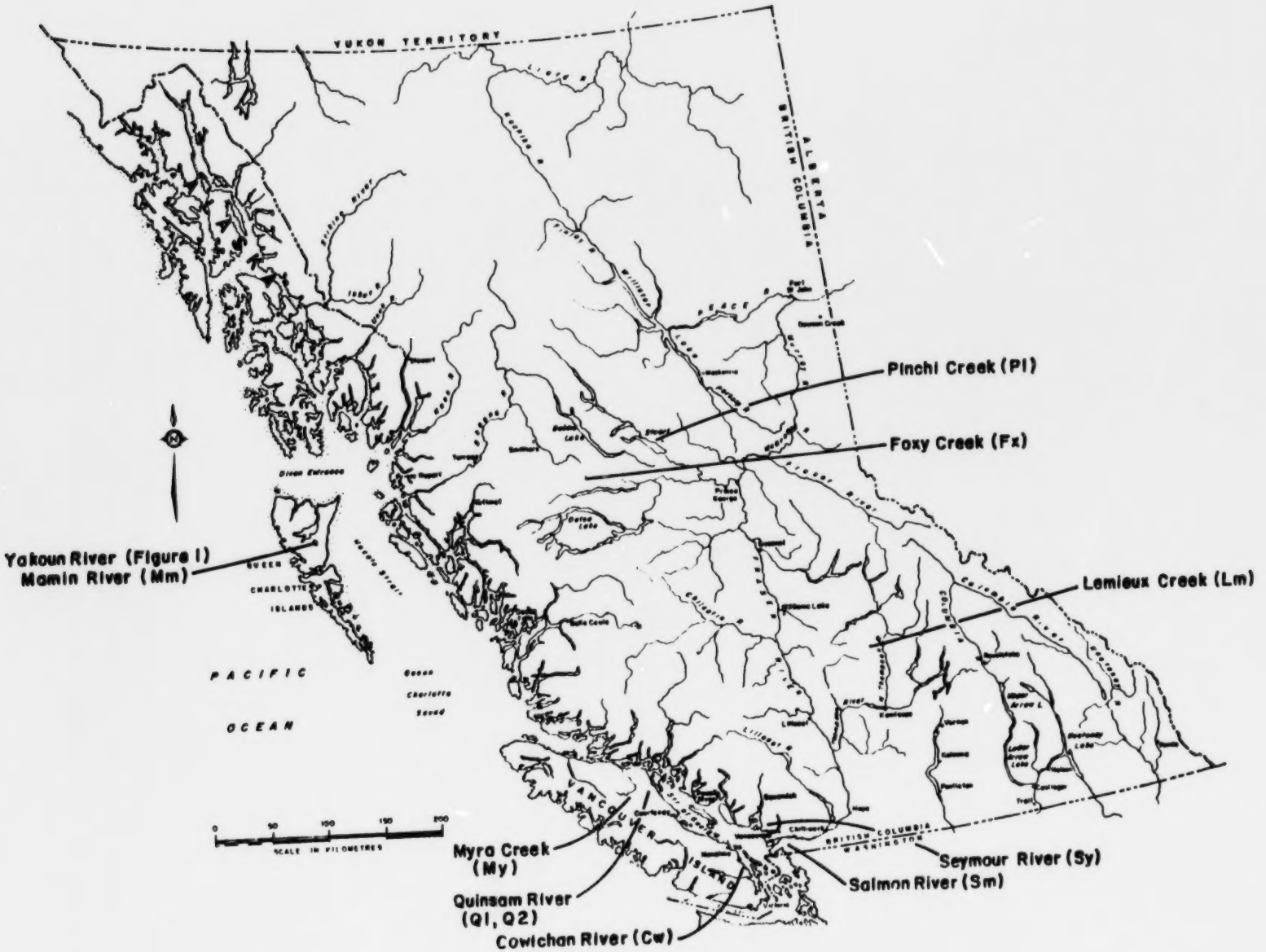

FIGURE 3 GENERAL LOCATION OF OTHER STREAMS SAMPLED FOR SEDIMENT

3 MATERIALS AND METHODS

3.1 Sampling

3.1.1 Stainless Steel Syringe Samples. Sediment samples were obtained using an 600 ml capacity stainless steel syringe modified after a sampler orignally designed to collect intragravel dissolved oxygen samples (Ryan, 1972). Some of the sampler tipholes were enlarged to 2.0 mm (Plate 1). The rubber O-rings were lightly lubricated with stopcock grease to ensure easy movement of the piston. Samples were collected from areas where spawning was known to occur or in gravelly areas of the stream.

The probe tip was worked into the substrate to a depth of 20-25 cm at all stations (11 cm at Station B2) and a sample was drawn up and evacuated into a clean 2 litre polyethylene sample bottle. Two separate samples were combined to make-up one replicate and three to five replicates were collected at each station for metal analyses. Additional samples were collected for particle size analysis and organic content.

To obtain the final sample, the content of each bottle was poured into a clean Imhoff cone and settled for one hour (Plate 2). The water in the cone was then decanted. The cone was inverted and the sediment fraction was drained into a kraft sediment bag. Distilled water was used to rinse any residual sediment into the kraft bag. The samples were kept frozen until preparation for analysis.

Between each sediment sample, the syringe was cleaned by drawing up a sample of creek water and then evacuating it. The sampler was dismantled between sample sites and rinsed with distilled water to remove any residual sediment.

3.1.2 Freeze Core Samples To assess if the syringe sampler mercury results were comparable to freeze core samples, freeze core samples were collected on one occasion using a sampler described by Walkotten, 1973. The probe was pushed into the streambed to 20-25 cm. The frozen sediment

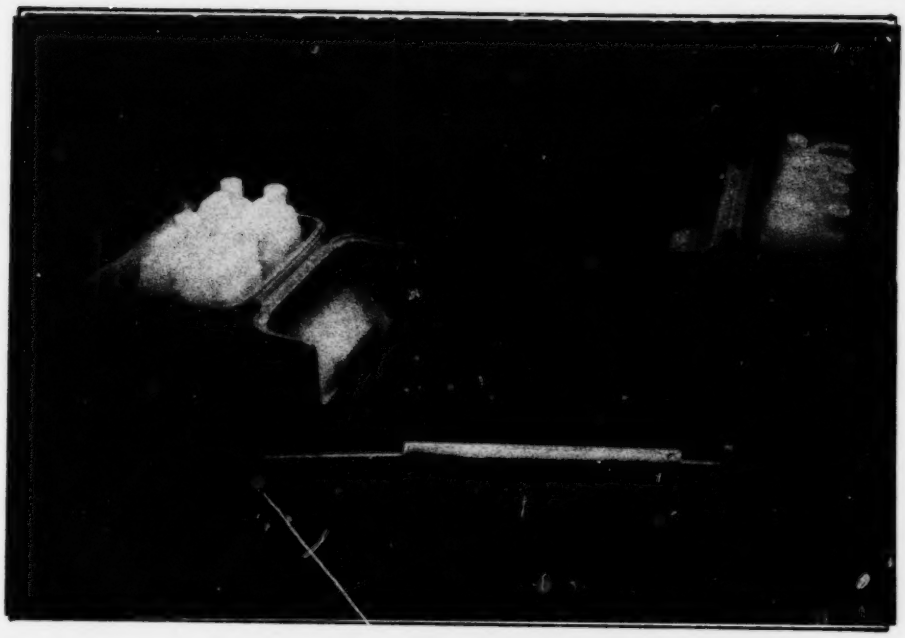

PLATE 1 - STAINLESS STEEL SYRINGE SAMPLER

PLATE 2 - Settled Sediment Showing Lower Granular Fraction and Upper Floccule Fraction

plug was pulled out and placed in a stainless steel bucket. With disposable gloves on, pieces of sample were broken off with a piece of rock from the stream and then placed in a whirl pac. Any residual left in the pail was rinsed into the whirl pac with distilled water. The samples were kept frozen until preparation for analysis.

3.1.3 Quality Control. To assess the degree of metal contamination from the syringe sampler, over the study period, samples of distilled water were drawn up and then evacuated into acid washed 200 ml polyethylene sample bottles. The samples for ICAP analysis were acidified with nitric acid to a pH of 1.5 and those for mercury analysis with 10 ml of nitric-dichromate acid.

The freeze core sampler was constructed of copper and brass. To determine if contamination of samples with Hg was possible, scrapings from the probe were put into distilled water and preserved with nitric-dichromate acid. Samples for As and other metal analyses were acidified with nitric acid to pH 1.5.

3.2 Analytical Methods

3.2.1 Sediment Samples. All analyses were performed at the EPS/DFO Laboratory in West Vancouver. Analytical procedures are outlined in the Laboratory Manual, 1979 or addendum sections. The method for sediment sample preparation is reported in Appendix II. Mercury was analyzed on a Pharmacia Mercury Monitor Model 100 and the other metals by Inductively Coupled Argon Plasma (ICAP) Atomic Emission Spectrometry. An elemental correction for vanadium was made to the ICAP between the analysis of the September 1982 and February 1983 samples. This may have also made differences to the arsenic, aluminum, beryllium and nickel results between the two surveys. The September 1982 samples were rerun for V, As, Al, Be and Ni. A factor change was made for cadmium on the ICAP in June 1983. This did not affect the Yakoun River and tributary stream results but applied to the other streams sampled.

Percent organic content was determined from a volatile sediment residue analysis. The prepared sample (1-10 gm) was air dried at 90°C overnight followed by drying at 103°C for one hour. The sample was then muffled at 550°C for one hour.

Particle size distribution was based on the following sieve size ranges: > 9.5 mm; > 2.36 mm, < 9.5 mm; > 1.18 mm, < 2.36 mm; > .3 mm, < 1.18 mm; > .15 mm, < .3 mm; > .075 mm, < .15 mm and < .075 mm. The proportion of each sample < .15 mm was determined for all samples.

3.2.2 Reference Sediment Samples. National Research Council reference samples BCSS1 and MESS1 were tested to evaluate the methods utilized by the DOE/DFO Laboratory. The reverse aqua regia digest is not a total digest for silica associated or refractory compounds.

3.2.3 Water Samples. Mercury samples were analyzed on a Pharmacia Mercury Monitor Model 100 and other metals by ICAP.

4 RESULTS AND DISCUSSION

4.1 Syringe Sampler Contamination

Eight samples were tested to assess the extent of contamination of distilled water drawn into the sampler (Table 1). There was no evidence of mercury contamination in any of the samples and only one of the eight samples had a detectable arsenic level. Metals that indicated some level of increase included zinc which increased from 4 $\pm$ 4 ug/l to 12 $\pm$ 11 ug/l, iron which increased from < 5 ug/l to 56 $\pm$ 44 ug/l and manganese which increased from < 1 ug/l to 10 $\pm$ 16 ug/l. These levels of contamination are significant in the context of using the sampler for collecting water samples but not for sediment samples. As well, the liquid portion of the sample is decanted prior to obtaining the sediment sample.

4.2 Freeze Core Sampler Contamination

Due to the samplers soft copper/brass construction, sediment samples collected by this method would result in Cd, Cu, Pb and Zn contamination (abrasion on larger rocks as sampler is installed) (Table 2). There was no evidence of mercury contamination or other metals such as As, Fe, Al, Mn and Mg.

4.3 Reference Samples

Results obtained by the analytical methods used in this study for the most part compared well with certified NRC reference samples. The exceptions for both reference samples included Ba, Be, Cr, Mo, Sr, Ti, V, Al, and Na which were lower (Table 3). In addition, for reference sample MESS 1, Mn and Ca were lower. For metals such as As, Cd, Co, Cu, Mg, Ni, Pb, Zn and Fe a close similarity between mean results was evident. For the EPS-ICAP analyses, the relative standard deviation ranged between 23-39% for As, 33-64% for Cd and 26-35% for Co. For all other metals the relative standard deviation was less than 10% (Table 3).

TABLE 1 CONTAMINATION CONTROL TESTS FOR STAINLESS STEEL SYRINGE

METAL*	DISTILLED WATER						SYRINGE DRAWN DISTILLED WATER									
					$\bar{x}$	S.D.									$\bar{x}$	S.D.
Hg	< .2	< .2	< .2	< .2	< .2	0	< .2	< .2	< .2	< .2	< .2	-	< .2	-	< .2	0
As	< .5	< .5	< .5	< .5	< .5	0	< .5	< .5	< .5	< .5	< .6	1.0	< .5	< .5	.6	.2
Ba	< .001	< .001	< .001	< .001	< .001	0	< .001	< .001	< .001	< .001	< .001	< .001	.001	.001	< .001	0
Be	< .001	< .001	< .001	< .001	< .001	0	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	0
Cd	< .002	< .002	< .002	< .002	< .002	0	< .002	< .002	< .002	< .002	< .002	< .002	< .002	< .002	< .002	0
Co	< .005	< .005	< .005	< .006	< .005	0	< .005	< .005	< .005	< .005	< .006	< .006	< .006	< .006	< .005	0
Cr	< .005	< .005	< .005	< .006	< .005	0	< .005	< .005	.006	.010	< .006	< .006	< .006	< .006	.006	.002
Cu	< .005	< .005	< .005	< .006	< .005	0	< .005	< .005	< .005	< .005	.010	< .006	.007	< .006	.006	.002
Mn	< .001	< .001	< .001	< .001	< .001	0	.002	.002	.002	.007	.049	.009	.003	.002	.010	.016
Mo	< .005	< .005	< .005	< .006	< .005	0	< .005	< .005	< .005	< .005	< .006	< .006	< .006	< .006	< .005	0
Ni	< .02	< .02	< .02	< .02	< .02	0	< .02	< .02	< .02	.03	< .02	< .02	< .02	< .02	.02	.004
P	< .05	< .05	< .05	< .06	< .05	0	< .05	< .05	< .05	< .05	< .06	< .06	< .06	< .06	< .05	0
Pb	< .02	< .02	< .02	< .02	< .02	0	< .02	< .02	< .02	< .02	< .02	< .02	< .02	< .02	< .02	0
Sn	< .01	< .01	< .01	< .01	< .01	0	< .01	< .01	< .01	< .01	< .01	< .01	< .01	< .01	< .01	0
Sr	< .001	< .001	< .001	< .001	< .001	0	< .001	< .001	< .001	< .001	.002	< .001	< .001	< .001	.001	0
Ti	< .002	< .002	< .002	< .002	< .002	0	< .002	< .002	< .002	< .002	< .002	< .002	.005	.002	.002	.001
V	< .01	< .01	< .01	< .01	< .01	0	< .01	< .01	< .01	< .01	< .01	< .01	< .01	< .01	< .01	0
Zn	< .002	< .002	.010	< .002	.004	.004	.005	< .002	.019	.035	.011	.003	.011	.007	.012	.011
Al	< .05	< .05	< .05	< .06	< .05	0	< .05	< .05	< .05	< .05	< .06	< .06	.06	.08	.06	.01
Fe	< .005	< .005	< .005	< .006	< .005	0	.011	.008	.050	.141	.062	.024	.084	.065	.056	.044
Si	< .1	< .1	< .1	< .1	< .1	0	< .1	< .1	< .1	< .1	< .1	< .1	< .1	.1	< .1	0
Ca	< .1	< .1	< .1	< .1	< .1	0	< .1	< .1	< .1	< .1	.7	< .1	< .1	< .1	.2	.2
Mg	< .1	< .1	< .1	< .1	< .1	0	< .1	< .1	< .1	< .1	< .1	< .1	< .1	< .1	< .1	0
Na	< .2	< .2	< .2	< .2	< .2	0	< .2	< .2	< .2	< .2	1.2	.2	< .2	< .2	.3	.4
	E	E	E	T			E	E	E	E	T	T	T	T		

* mg/l except Hg and As as ug/l
E = extractable ICAP
T = total ICAP

TABLE 2 CONTAMINATION TEST FOR FREEZE CORE SAMPLES

TOTAL METAL*	DISTILLED	SPIKED DISTILLED**
Hg	< .2	< .2
As	< .05	< .05
Ba	< .001	< .001
Be	< .001	< .001
Cd	< .002	[.735]
Co	< .005	< .005
Cr	< .005	< .005
Cu	< .005	[14.8]
Mn	.004	< .001
Mo	< .005	< .005
Ni	< .02	< .02
P	< .05	[.52]
Pb	< .02	[.35]
Sn	< .01	< .01
Sr	< .001	< .001
Ti	< .002	< .002
V	< .01	< .01
Zn	< .002	[4.57]
Al	.07	< .05
Fe	.014	.008
Si	< .1	< .1
Ca	.2	< .1
Mg	.1	< .1
Na	< .2	< .2

*mg/l except Hg as ug/l
**spiked with filings from the probe
[ ] - contamination evident

TABLE 3 NRC REFERENCE SEDIMENT DATA FOR 1983

METAL	EPS - ICAP* (PCSS 1)				NRC - PCSS 1		EPS - ICAP* (MESS 1)				NRC - MESS 1	
(ug/g)	n	$\bar{x}$	(S.D.)	R.S.D. (%)	Certified $\bar{x}$	(± 95%)	n	$\bar{x}$	(S.D.)	R.S.D. (%)	Certified $\bar{x}$	(± 95%)
As	14	9.6	(3.7)	39	11.1	(1.4)	12	8.9	(2.1)	23	10.6	(1.2)
Ba	14	55.7	(5.5)	9.8	350		12	48.1	(3.1)	6.5	270	
Be	14	0.56	(0.05)	8.8	1.3	(0.3)	12	0.68	(.05)	6.7	1.9	(0.2)
Cd	14	0.35	(0.12)	33	0.25	(0.04)	12	0.49	(.31)	64	0.59	(0.1)
Co	14	8.4	(3.0)	35	11.4	(2.1)	12	8.3	(2.2)	26	10.8	(1.9)
Cr	14	56.3	(4.2)	7.5	123	(14)	12	32.3	(1.4)	4.2	71	(11)
Cu	14	16.5	(0.7)	4.5	18.5	(2.7)	12	26.0	(1.8)	6.8	25.1	(3.8)
Mn	14	211	(6)	2.9	229	(15)	12	353	(12)	3.4	513	(25)
Mo	14	0.83	(0.07)	8.8	1.9		12	0.83	(0.08)	9.3	2.2	
Ni	14	51.8	(2.3)	4.4	55.3	(3.6)	12	23.3	(1.5)	6.3	29.5	(2.7)
P	14	739	(18)	2.5	672	(70)	12	650	(17)	2.6	637	(61)
Pb	14	18.9	(1.5)	8.0	22.7	(3.4)	12	30.0	(2.1)	7.1	34.0	(6.1)
Sn	14	< 2			3		12	< 2			6	
Sr	14	35.6	(1.5)	4.3	96		12	30.6	(1.3)	4.3	89	
Ti	14	316	(34)	11	4400	(144)	12	438	(39)	8.8	5430	(168)
V	14	48.2	(2.7)	5.6	93.4	(4.9)	12	37.6	(1.4)	3.8	72.4	(5.3)
Zn	14	110	(2.4)	2.2	119	(12)	12	184	(6)	3.4	191	(17)
Al (%)	14	2.27	(0.16)	7.2	6.26	(0.22)	12	1.79	(0.08)	4.6	5.84	(0.2)
Fe (%)	14	2.74	(0.07)	2.5	3.29	(0.10)	12	2.39	(0.07)	2.9	3.05	(0.17)
Ca	14	4329	(130)	3.0	5430	(530)	12	2488	(95)	3.8	4810	(460)
Mg (%)	14	1.19	(0.04)	3.6	1.47	(0.14)	12	.665	(.024)	3.7	.868	(.054)
Na (%)	14	.83	(0.04)	4.3	2.02	(0.16)	12	0.64	(0.03)	4.2	1.85	(0.11)
Hg**	18	.239	(.076)	32	0.129	(0.012)	13	.315	(.108)	34	0.171	(0.014)

*reverse aqua regia digest (not a total digest for silica associated or refractory compounds)
**Hg analyzed on Pharmacia Mercury Monitor
R.S.D. = relative standard deviation

For mercury, the EPS mercury results were higher than the reference samples and the relative standard deviation was 32-34% (Table 3).

4.4 Particle Size Analysis

Freeze core samples from the area of streambed that syringe samples were collected indicated that the < .15 mm fraction made up < 0.5% of the total sample for Yakoun-1 and < 3.1% for Florence-1 (Table 4). For the syringe samples, the < .15 mm fraction made up 45-49% of the sample for Yakoun-1 and 60-71% for Florence-1. The syringe method collects an adequate sample of the < .15 mm fraction, used for metal analyses and minimizes the need to sieve out the large fractions.

4.5 Organic Content

Organic content was not measured on the September 1982 samples. For the February syringe samples, Barbie-2 had the highest organic content ($\bar{x}$ = 26.5%) and Yakoun-2 the least ($\bar{x}$ = 6.4%) (Table 5). Organic content was measured on two freeze core samples collected at Barbie-3 ($\bar{x}$ = 13.3%). The syringe samples at the same location had a mean organic content of 13.6%.

4.6 Heavy Metal Content of Intergravel Fine Sediments

Results for the September 1982 and February 1983 metal analyses on Barbie Creek, Yakoun River, Canoe Creek and Florence Creek are presented in Appendix III. Results for the other streams sampled are presented in Appendix IV.

4.6.1 Sampler Differences (at Barbie-3). A comparison was made at Barbie-3 between the metal concentration of samples collected with the syringe sampler and the freeze core sampler. The results indicated that significant differences exist between the two methods, although both analyses were on the < 150 um fraction. A T-test indicated sample means were significantly different ($P < .05$) for Hg, As, Ba, Co, Cr, Sn and Fe (Table 6).

TABLE 4 PARTICLE SIZE DISTRIBUTION OF FREEZE CORE AND SYRINGE SAMPLES

SIZE RANGE (mm)	YAKOUN-1 (SEPTEMBER 15, 1982)				FLORENCE-1 (SEPTEMBER 15, 1982)			
	Freeze Core		Syringe		Freeze Core		Syringe	
	i	ii	i	ii	i	ii	i	ii
> 9.5 (%)	60.6	18.9	0	0	84.4	56.5	0	0
> 2.36 , < 9.5 (%)	28.3	54.8	0	0	10.6	14.6	0	0
> 1.18 , < 2.36 (%)	6.7	14.5	3.5	3.7	2.5	3.9	0.8	0
> .30 , < 1.18 (%)	4.0	10.8	37.5	41.4	1.8	18.3	16.9	10.2
> .15 , < .30 (%)	0.2	0.5	10.5	10.2	0.2	3.6	24.4	18.9
> .075 , < .15 (%)	0.1	0.2	17.3	12.0	0.2	1.3	32.3	34.8
< .075	0.1	0.3	31.2	32.7	0.3	1.8	25.6	36.0
< .15 (%)	0.2	0.5	48.5	44.7	0.5	3.1	57.9	70.8

TABLE 5 PERCENT ORGANIC CONTENT OF < 150 um SEDIMENT FRACTION

	BARBIE CREEK						YAKOUN RIVER				CANOE CREEK		FLORENCE CR	
	1		2		3		1		2		1		1	
	i	ii	i	ii	i	ii	i	ii	i	ii	i	ii	i	ii
Syringe Samples														
Sep. 82	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Feb. 83	10.4	10.8	29.3	23.7	11.5	15.7	6.6	8.2	6.5	6.1	19.9	20.1	16.9	19.0
Freeze Core Samples														
Feb. 83	-	-	-	-	13.6	12.9	-	-	-	-	-	-	6.7	-

TABLE 6 COMPARISON OF HEAVY METAL CONCENTRATION OF INTERGRAVEL FINE SEDIMENTS COLLECTED BY FREEZE CORE SAMPLER AND SYRINGE SAMPLER AT BARBIE-3 (February 22, 1983)

METAL*	FREEZE CORE						SYRINGE						
	1	2	3	4	$\bar{x}$	S.D.	1	2	3	4	5	$\bar{x}$	S.D.
[Hg]**	.16	.17	.17	.13	.16	.02	.32	.30	.27	.33	.37	.32	.04
[As]	99	112	157	84	113	31	34	40	34	47	55	42	9
[Ba]	546	304	379	478	427	107	181	186	214	191	224	199	19
Be	.5	.4	.6	.4	.5	.1	.4	.3	.3	.4	.4	.4	.1
[Co]	115	77.7	101	89.3	95.7	15.9	20.9	20.6	23.2	25.5	29.3	23.9	3.6
[Cr]	29.9	30.1	30.1	37.1	31.8	3.5	51	48	65	53	48	53	7
Ni	31	16	25	36	27	9	28	23	39	29	55	35	13
[Sn]	5	5	6	6	5	1	3	3	5	3	3	3	1
Sr	80.5	81	74.1	221	114	71	86.7	78.3	117	80	72.8	87	17.5
V	99	111	119	113	110	8	108	104	100	107	105	105	3
Al	34500	39000	38600	38400	37625	2098	41000	38300	39800	39500	37700	39260	1297
[Fe]	67100	69000	84100	63700	70975	9020	48800	51400	48500	51100	56600	51280	3249
Si	3760	5150	5200	4800	4727	669	4630	5600	5220	5600	5320	5274	398
Ca	5000	5330	5220	7120	5667	978	5000	5030	5860	4790	4700	5076	460
Mn	7400	7750	6610	10800	8140	1836	8750	7920	9190	8020	7400	8256	710
Na	520	510	420	850	575	189	570	600	750	550	520	598	90

* ICAP, < 0.15 mm Fraction, as ug/g

** Hg, (Pharmacia Mercury Monitor)

[] significantly different (T-test, $P < .05$)

The mean mercury concentration for the freeze core sample was 0.16 ug/g (S.D. = .02) compared to 0.32 ug/g (S.D. = .04) for the syringe samples. Analysis of the freeze core probe did not indicate a contamination problem with Hg, As or the other metals listed (Table 2). The reason for these differences is not readily explained and further work is required to assess this variability. A comparison of a set of samples fractioned by eye into a floccule fraction and granular fraction (Plate 2) indicated higher mercury levels occurred in the floccule fraction (Table 7). The floccule fraction contained 48-91% of the < 150 um fraction and the granular fraction contained 4-16% of the < 150 um fraction (Table 7).

There are some significant differences in the results of these two sample methods. The method of obtaining samples for metal analysis from clastic stream sediments could be a significant factor in determining pre-development (baseline) levels and post-development (impact) trends.

The mercury levels for the February 1983 freeze core samples are low at Barbie-3 compared to samples collected by EPS in 1981/82 (unpublished data, Appendix V). Mercury results collected over 1981 to 1983 at Barbie-3 are shown on Figure 4. The arsenic level of the freeze core sampler in February 1983 ($\bar{x}$ = 113 ug/g, S.D. = 31) is similar to that in March 1982 ($\bar{x}$ = 123 ug/g, S.D. = 19) as are the Al and Fe results (Appendix II, V).

4.6.2 Mercury (syringe samples). The mean mercury levels of sediment samples collected from the B.C. streams monitored to date indicate the Barbie-3 (September, 1982) samples had the highest overall mean of 0.47 ug/g (Figure 5, Appendix III, IV). On both the September 1982 and February 1983 surveys, Barbie-3 had a higher mean mercury level than the upstream control Barbie-1. This may reflect the reported high levels of mercury associated with the Cinola mine property. A T-test indicated that the seasonal differences between mean mercury levels for the stations monitored on the Yakoun drainage were significantly different ($P < .05$) for Barbie Creek stations 1 and 3 and Canoe Creek station 1.

TABLE 7 MERCURY CONCENTRATION AND PARTICLE SIZE DISTRIBUTION OF FLOCCULE AND GRANULAR FRACTIONS OF INTERGRAVEL FINE SEDIMENTS (syringe samples) - SEPTEMBER 15, 1982

	B1		B2		B3		Y1		Y2		C1		F1	
	F	G	F	G	F	G	F	G	F	G	F	G	F	G
Hg (ug/g)	.31	.17	.34	.25	.38	.34	.25	.15	.20	.13	.27	.11	.40	.24
% ≥ .15 mm	9	94	40	90	52	84	49	95	35	94	45	96	18	93
% < .15 mm	91	6	60	10	48	16	51	5	65	6	55	4	82	7

F = floccule fraction which settled out as a layer over granualr material

G - granular layer

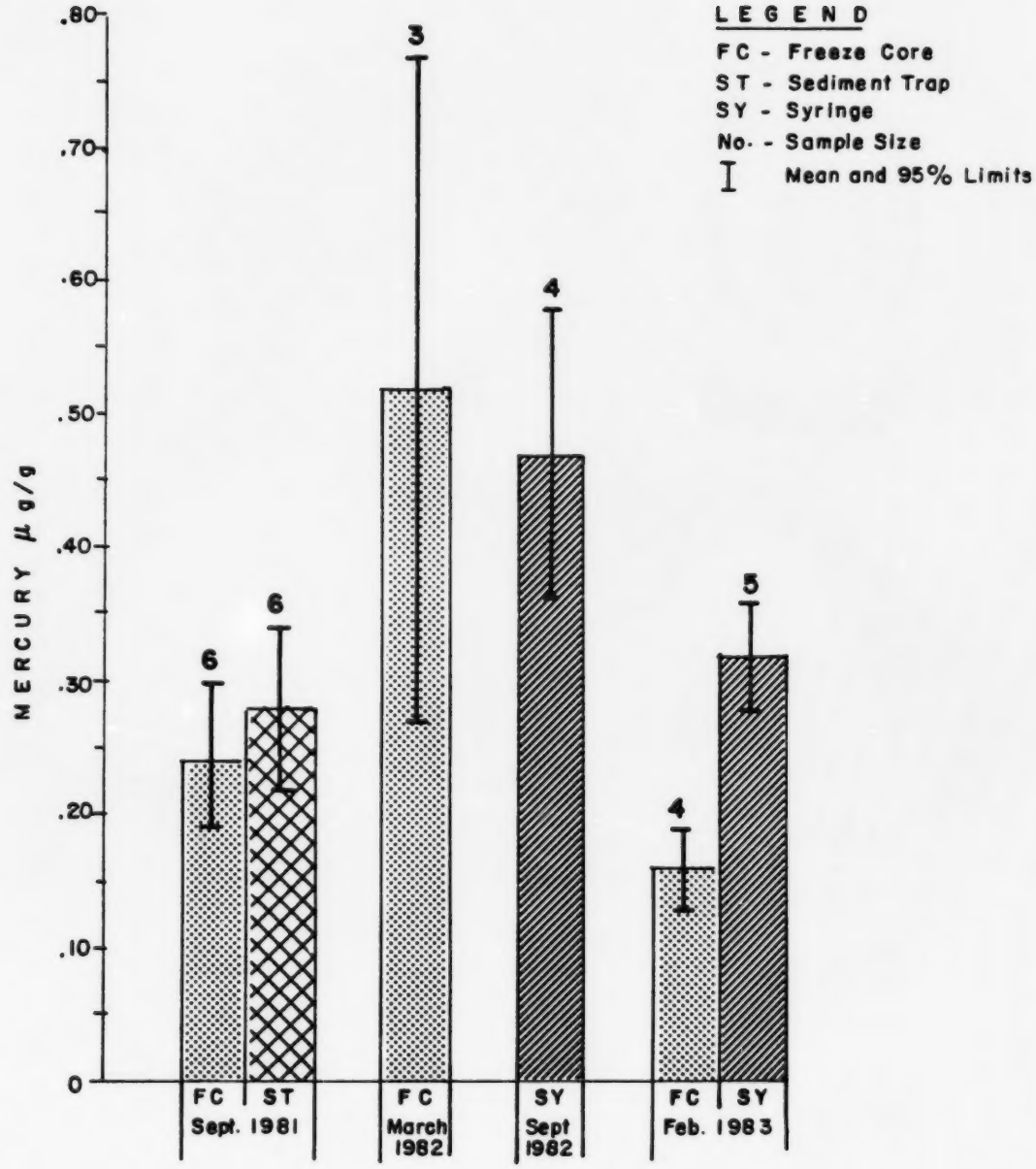

FIGURE 4 MERCURY LEVELS AT STATION BARBIE 3 OVER 1981 TO 1983

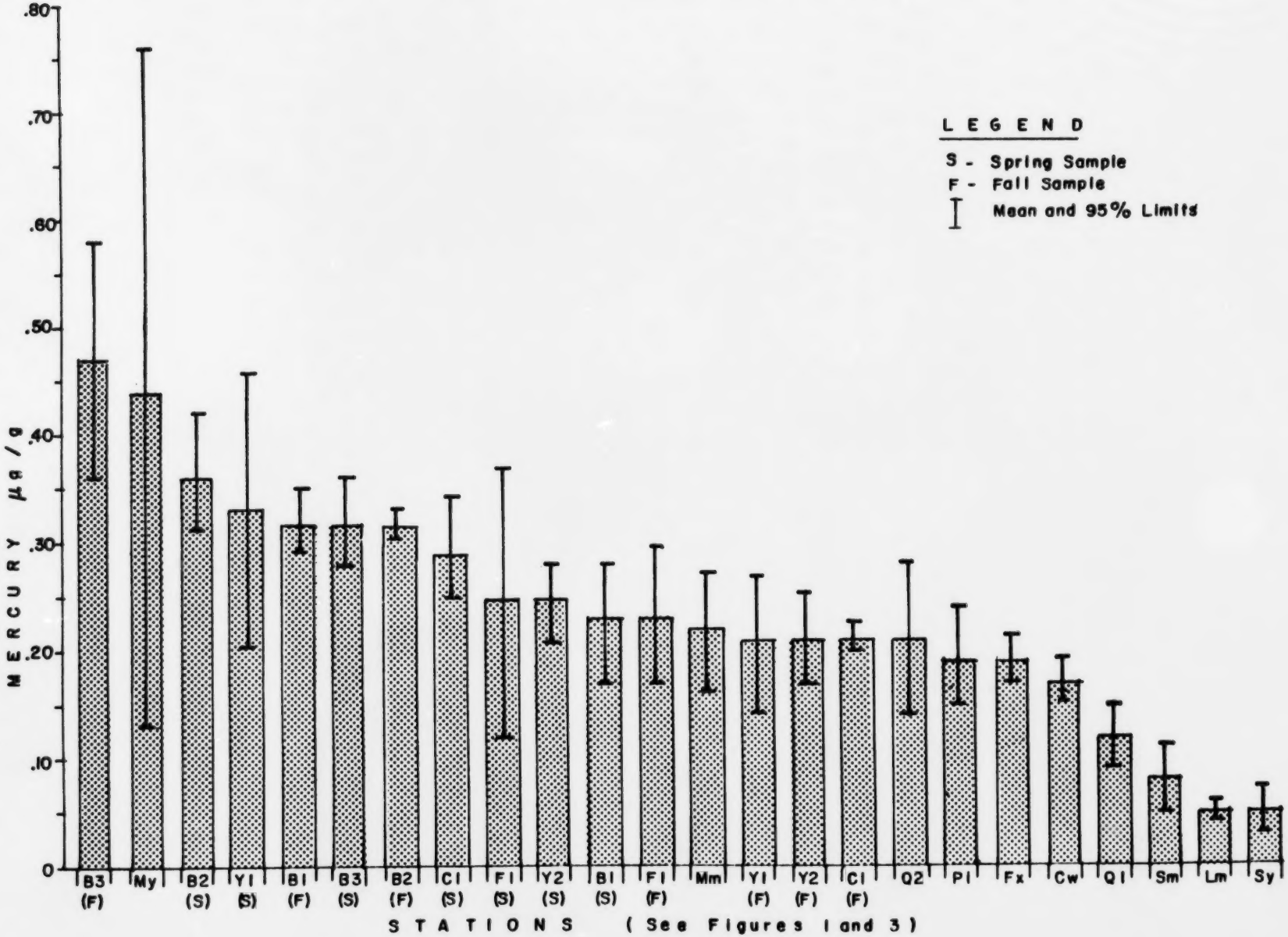

FIGURE 5 SYRINGE SAMPLER SEDIMENT MERCURY LEVELS

Sediment samples from Pinchi Creek had a mean mercury content of 0.19 ug/g (Appendix IV). Pinchi Creek drains Pinchi Lake the northern edge of which lies along the Pinchi fault zone (Siegel et al., 1985). Mercury was actively mined from a high grade cinnabar lode deposit near Pinchi Lake from 1940 to 1944.

4.6.3 **Arsenic (syringe samples).** The mean sediment arsenic levels indicate the Barbie Creek system has high levels compared to the other streams monitored in B.C. (Figure 6, Appendices III and IV). Again, these levels likely reflect the nature of Cinola mine property. Stations Barbie-2 (February 1983) and Barbie-3 (September 1982) had the highest mean concentrations (63 ug/g and 62 ug/g respectively).

4.6.4 **Zinc (syringe samples).** The highest mean zinc levels were recorded for Lemieux Creek (164 ug/g) and Foxy Creek (156 ug/g) (Figure 7, Appendices III and IV). For the Yakoun River drainage, station Barbie-3 had the next highest mean concentration of 127-130 ug/g) (Figure 7).

4.6.5 **Copper (syringe samples).** The highest mean copper level (86 ug/g) was recorded for the Quinsam River at station Q-1 (Figure 8, Appendices III and IV). The highest mean copper level for a Yakoun drainage station was 40 ug/g at station Yakoun-2 (Figure 8).

4.6.6 **Iron (syringe samples).** Results for sediment iron levels are shown in Figure 9. Florence Creek had the highest mean iron content (5.9%) followed by Barbie-3 (5.1%) (Figure 9, Appendices III and IV).

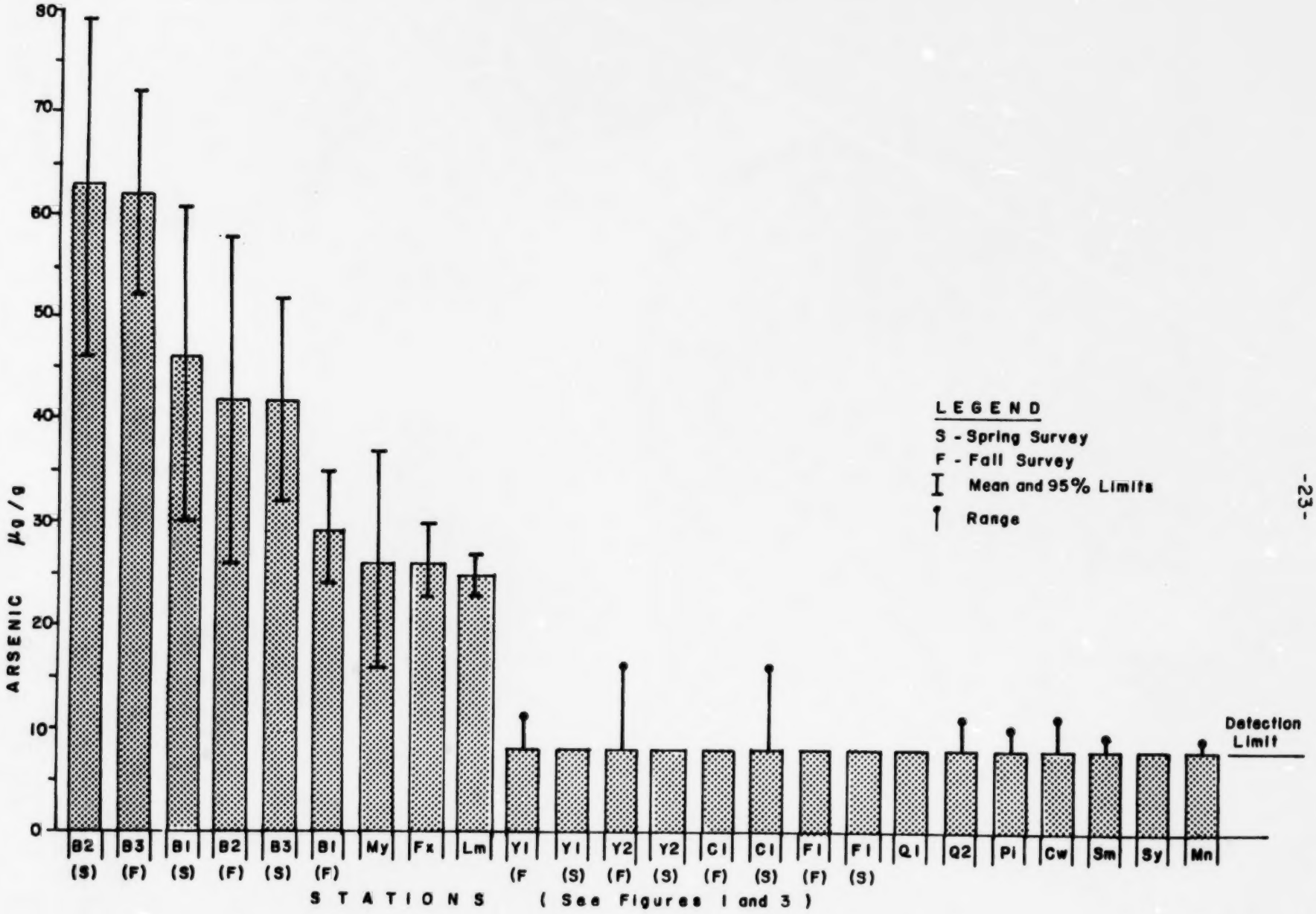

FIGURE 6 SYRINGE SAMPLER SEDIMENT ARSENIC LEVELS

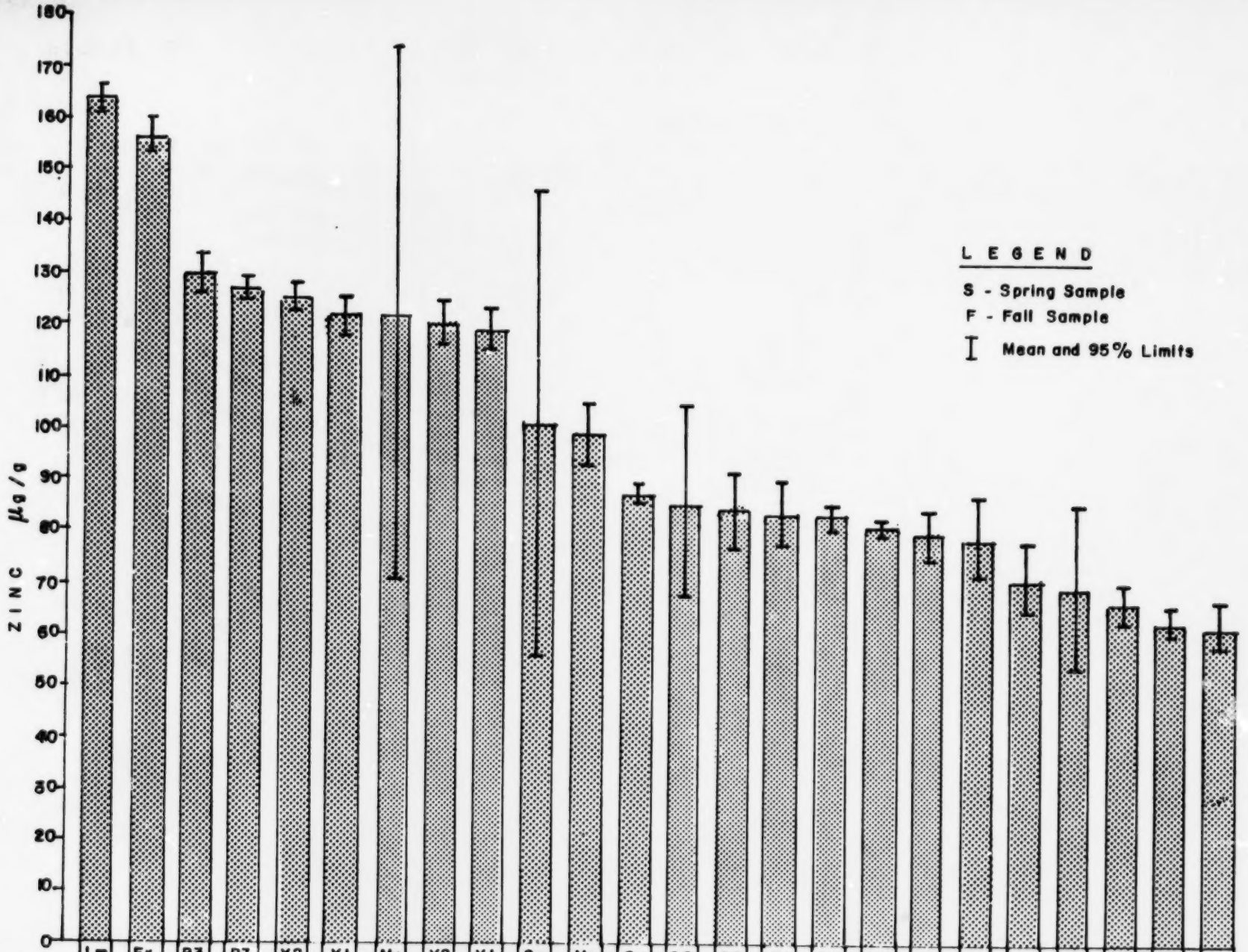

FIGURE 7 SYRINGE SAMPLER SEDIMENT ZINC LEVELS

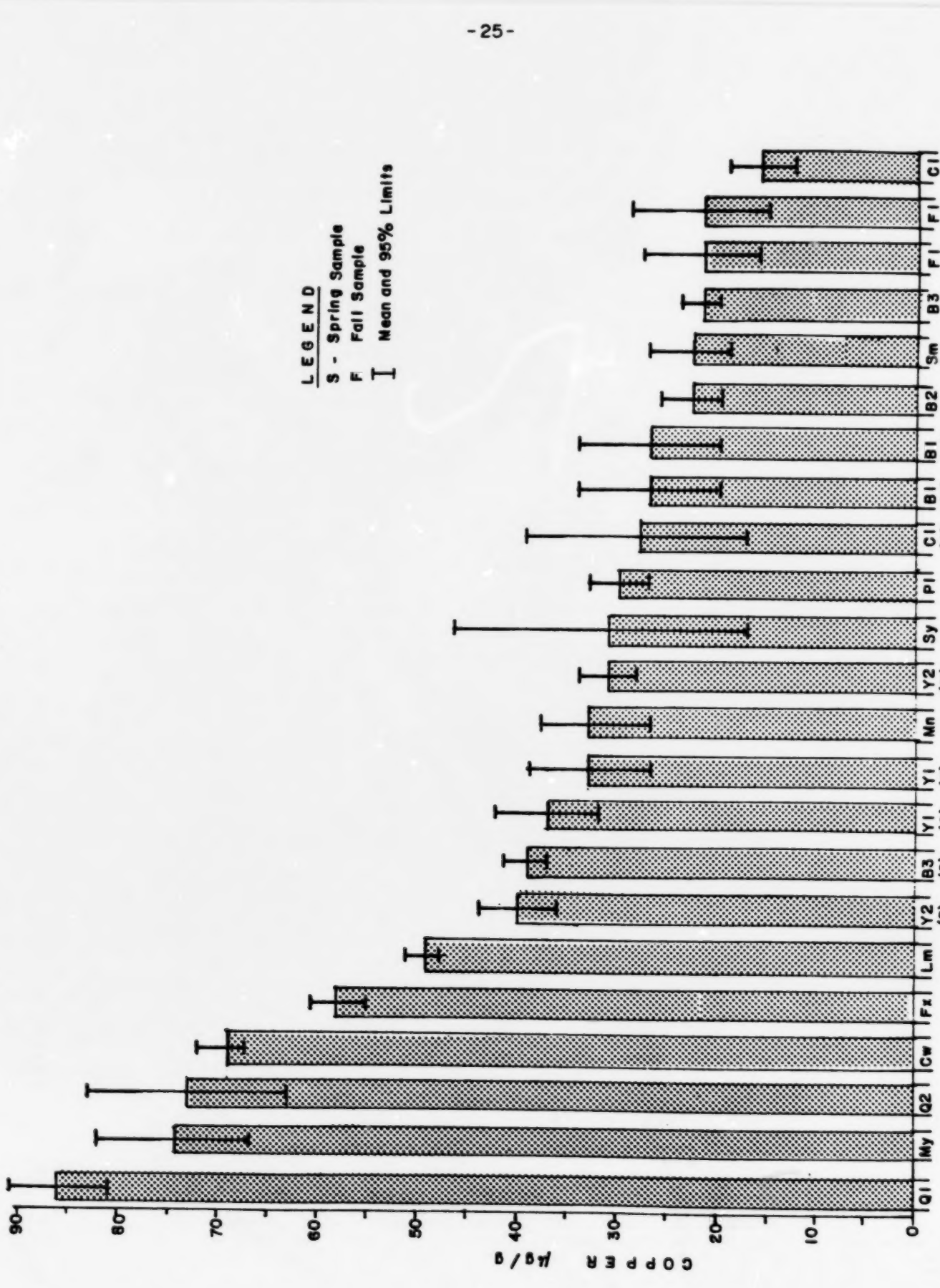

FIGURE 8 SYRINGE SAMPLER SEDIMENT COPPER I FVFIS

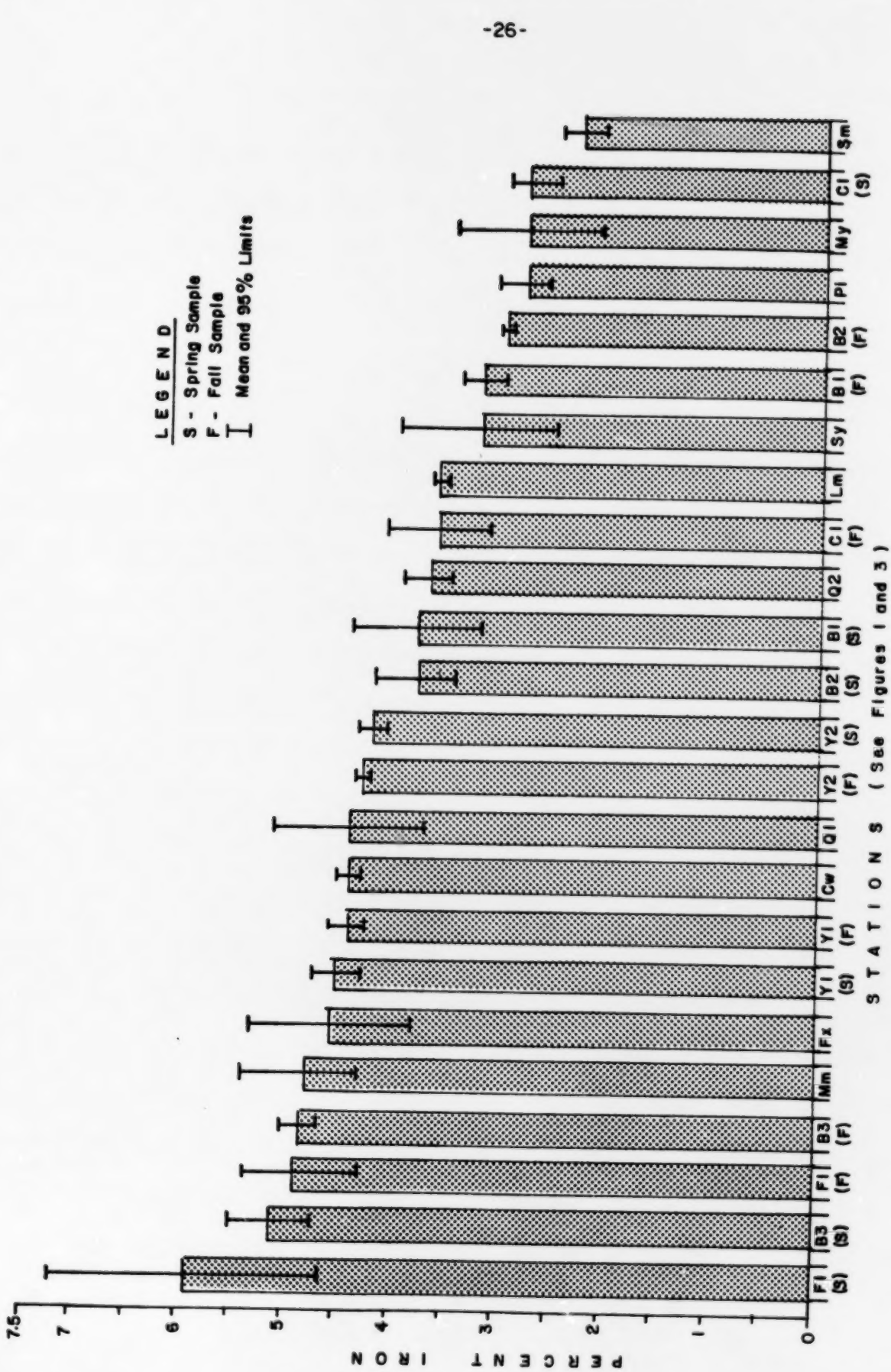

FIGURE 9 SYRINGE SAMPLER SEDIMENT IRON LEVELS

5 THE VALUE OF SEDIMENT MONITORING NEAR MINE SITES

Maintaining the quality of a stream bed made up of clastic material is an important aspect of environmental protection. The growth, development and survival of salmon eggs and alevin in clastic sediments are dependant on the physical and chemical characteristics of the intragravel water. To prosper, an embryo or alevin must receive an ample supply of oxygenated water of suitable temperature and free of toxic substances (McNeil and Ahnell, 1964). The transfer of metals between bottom materials and the water is a complex process depending on a multitude of factors such as the dissolved oxygen concentration, the nature and the concentration of heavy metals, the organic and inorganic ligands present, the pH and the particle size of the bottom sediments (Taylor and Demayo, 1980). Detritus in the form of fine (50-1000 um) and ultrafine (0.5-50 um) particulate organic matter is an important food source of filtering and gathering herbivorous insects (Cummins and Klug, 1979; Vannote et al., 1980). Forstner and Wittman, 1979 reported that these organisms could be affected by heavy metals occurring in their environment. There is a general increase of metal concentrations from coarse to finer-grained fractions and the affinity of heavy metals for organic substances and for their decomposition products is well recognized.

Birge et al., 1977 reported that the survival of trout embryos and alevins closely paralleled sediment test metal (Cd, Hg, Zn) concentrations. Sediment metals were substantially more lethal to eggs and embryos than to free living fish. The sediment TL_{50} concentrations for trout stages cultured from 10 days prehatching through 10 days post-hatching were approximately 1 ppm for mercury, 2.15 ppm for cadmium and 210.6 ppm for zinc. Cairns et al., 1984 reported that based on a dry-weight sediment copper concentration, the 10-d LC_{50} for the midge Chironomus tentans was 857-2296 ug/g. Malueg et al 1984 reported that stream sediments contaminated with copper (550-2700 ug/g) from mine tailings were significantly more toxic to the burrowing mayfly Hexagenia limbata than nonimpact control sediments (16-60 ug/g).

The occurrence, distribution and pollution effects of heavy metals in the aquatic environment has received extensive review (Hawkes and Webb, 1962; Hawkes 1976; Forstner and Wittman, 1979). Clastic stream sediments are composed predominantly of the residual and relatively insoluble products of weathering but during the course of transport along the streambed, the particle size is liable to be progressively reduced by chemical and physical disintegration (Hawkes and Webb, 1962).

Forstner and Wittman, 1979 reported that it is usually difficult to distinguish between contamination of industrial origin, "natural" pollution and pollution resulting from mining activities. Airborne dust and particulate material from smelter stacks, wind-blown particles and leachate from tailings ponds all contribute to an increase in the metal concentrations in river sediments. In order to measure changes due to a mine development, pre-monitoring data must be reproducible and have a measureable level of confidence. Thus, quantitative techniques are needed to establish these requirements. The syringe sampler used in this study fulfills those requirements to assess sediment metal levels in clastic stream sediments important to salmonids and invertebrates. While elevations in metal levels may be documentable, the significance and availability of these metals to various biological components requires further research.

REFERENCES

Birge, W.J., J.A. Black, A.G. Westerman, P.C. Francis and J.E. Hudson. Embryopathic Effects of Waterborne and Sediment-Accumulated Cadmium, Mercury and Zinc on Reproduction and Sruvival of Fish and Amphibian Populations in Kentucky. University of Kentucky, Water Resources Research Institute, Research Report No. 100 (1977).

Cairns, M.A., A.V. Nebeker, J.H. Gakstatter and W.L. Griffis. Toxicity of Copper- Spiked Sediments to Freshwater Invertebrates. Environmental Toxicology and Chemistry. 3; 435-445 (1984).

Cummins, K.W., and M.J. Klug. Feeding Ecology of Stream Invertebrates. Ann. Rev. Ecol. Syst. 10, 147 (1979).

Fanning, M.L., and T.C. Griffing, Stage I Submision to Steering Committee for Development of New Metal Mines. Prepared for Consolidated Cinola Mines Ltd. by IEC Consultants (July, 1980).

Forstner, U., and G.T.W. Wittmann. Metal Pollution in the Aquatic Environment. Springer-Verlag, Berlin, Heidelberg, New York, (1979).

Hawkes, H.E. The Downstream Dilution of Stream Sediment Anomalies. Journal of Geochemical Exploration 6: 345-358 (1976).

Hawkes, H.E., and J.S. Webb. Geochemistry in Mineral Exploration. Harper & Row, Publishers, New York and Evanston (1962).

Laboratory Manual, Department of Environment and Department of Fisheries and Oceans (Pacific Region) (1979).

Malueg, K.W., G.S. Schuytema, J.H. Gakstatter and D.F. Krawczyk. Toxicity of Sediments from three Metal-Contaminated Areas. Environmental Toxicology and Chemistry. 3: 279-291 (1984).

McNeil, W.J., and W.H. Ahnell. Success of Pink Salmon Spawning Relative to Size of Spawning Materials. U.S.F.W.S. Special Scientific Report, Fisheries 469 (1964).

Ryan, P. Subgravel Monitoring Equipment, D.O. Monitor Mark 11. Fisheries and Oceans Canada Drawing 4-6-142 (1972).

Siegel, S.M., B.Z. Siegel, C. Lipp, A. Kruckeberg, G.H.N. Towers and H. Warren. Indicator Plant-Soil Mercury Patterns in a Mercury Rich Mining Area of British Columbia. Water, Air and Soil Pollution 25: 73-85 (1985).

Taylor, M.C., and A. Demayo. Guidelines for Surface Water Quality. Vol. 1 - Inorganic Chemical Substances, Inland Waters Directorate, Ottawa (1980).

Vannote, R.L., G.W. Minshall, K.W. Cummins, J.R. Sedell and C.E. Cushing. The River Continuum Concept. Can. J. Fish. Aquat. Sci. 37, 130 (1980).

Walkotten, W.J. A Freezing Technique for Sampling Streambed Gravel. USDA Forest Service Research Note PNW 205 (1973).

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APPENDIX I

DESCRIPTION OF
SAMPLE STATION LOCATIONS

APPENDIX I DESCRIPTION OF SAMPLE STATION LOCATIONS

RIVER/CREEK	STATION NUMBER*	DESCRIPTION
Yakoun River	Y1	Located approximately 1.3 km downstream of Gold Creek on the north side. Access at a turnoff on Branch 40. The turnoff is located 1.2 km west of the Branch 40/Branch 47 junction. Sampled mid-stream where pink salmon were observed to spawn.
	Y2	Located approximately 0.6 km downstream of Barbie Creek on the north side. Access at turnoff on Branch 40. The turnoff is located 0.5 km west of where Barbie Creek flows under Branch 40. Sampled midstream where pink salmon were observed to spawn.
Barbie Creek	B1	Located upstream of Cinola Property in forested area. Approximately 30 m upstream of flagging tape marked COR OE 1 + 50. Gravel substrate and coho salmon observed at this site.
	B2	Located approximately two-thirds way along road branching off to Cinola pilot plant. Creek runs along north side of road. Approximately 15 cm of gravel overlaying peat base. Sediment samples from 11 cm depth. Coho salmon observed spawning in this area.
	B3	Located in gravel section half-way between Branch 40 road and the Yakoun River. Coho salmon observed to spawn at this site.
Canoe Creek	C1	Located on upstream side of Yakoun logging road bridge crossing lower Canoe Creek. Gravel substrate.
Florence Creek	F1	Located approximately 45 m upstream of Main Line road bridge crossing Florence Creek. Gravel substrate. Coho observed spawning in this area.
Cowichan River	Cw	Sampled July 27, 1983. Midstream in gravel area opposite Rotary Park, 0.5 km downstream of Highway #1. Chum salmon spawning area.

*(See Figures 1 and 3)

CONTINUED...

APPENDIX I DESCRIPTION OF SAMPLE STATION LOCATIONS

RIVER/CREEK	STATION NUMBER*	DESCRIPTION
Foxy Creek	Fx	Sampled July 18, 1983. In gravel area downstream of Equity Mine seepage reclaim pond.
Lemieux Creek	Lm	Sampled October 10, 1983. Midstream in gravel area upstream of Eakin Creek.
Mamin River	Mm	Sampled November 3, 1983. In gravel area. At end of road turnoff approximately 0.6 km downstream of Juskatla Road branch.
Myra Creek	My	Sampled May 18, 1983. In gravel area at EPS station M1 just downstream of powerhouse at Westmin Mine.
Pinchi Creek	Pi	Sampled July 20, 1983. In gravel area immediately upstream of bridge crossing (approx. 2 km upstream of Stuart Lake).
Quinsam River	Q1	Sampled June 22, 1983. In gravel area upstream of Argonaut Road crossing. Upstream of Middle Quinsam Lake.
	Q2	Sampled June 22, 1983. In gravel area downstream of Argonaut Road crossing, downstream of Middle Quinsam Lake.
Salmon River	Sm	Sampled August 10, 1983. Midstream in gravel area upstream of 56th Avenue.
Seymour River	Sy	Sampled August 10, 1983. In gravel area of river running parallel to Edgewater Lane.

*(See Figures 1 and 3)

APPENDIX II

SEDIMENT SAMPLE PREPARATION AND REVERSE AQUA REGIA DIGEST PROCEDURE

APPENDIX II SEDIMENT SAMPLE PREPARATION AND REVERSE AQUA REGIA DIGEST PROCEDURE

1) Transfer sample material into labelled KRAFT soil sample envelopes, dry samples @ 60°C., until completely dry.

2) When samples are dry, disaggregate the sample material by rapping the sample bag with a rubber mallet. Occasionally, the sample bag may split, this usually occurs when the samples are marine sediments or if the bags are hit too hard. If particle sizing has been requested, split the sample material on a riffle - a normal split is ¼ for metals and ¾ for particle sizing. Ensure that the sample splits are done in a manner that minimizes biasing of the subsamples. If the particle sizing request is for only the +/- 100 mesh (0.150 mm) fractions sample splitting is not required.

3) Sieve samples through a 100 mesh (.150 mm) stainless steel screen, store the fine fraction in a labeled vial, retain the coarse fraction if requested.

4) Weigh 0.30 to 0.32 g of seived sample into calibrated 50 ml test tubes. Replicate samples, reference materials, and reagent blanks must be included with every set of samples. Normally one reference material and one blank should be run with every set of 30 or less samples, the number of replicates should be at least the square root of the number of samples in a given lot. Use computer program "SEDWT" to set up a weight file and take weights directly from the balance.

5) Add 4.5 ml concentrated NITRIC acid, 1.5 ml concentrated HYDROCHLORIC acid, swirl solution vigorously, allow to react for 30 minutes, then add 10.0 ml DI water. Reagents should be dispensed with automatic pipettors, use only "BAKER - INSTRA-ANALYZED" acids (used for trace metal analysis).

6) Place test tubes into pre-heated block and heat for three hours. Sample solutions should boil gently during the digestion period - exercise care with very fine grained samples, they are likely to cause bumping problems. Bring volume of sample down to approximately 12 ml in order to compromise for equal matrix of reagents, as are used in ICP and GFAA analysis.

7) Remove test tubes and allow to cool before diluting sample solutions to 50.0 ml. Cap test tubes and mix well, allow sample solutions to settle out overnight. Carefully decant sample solutions into 30 ml acid washed poly bottles, ensuring that particulate material is not transferred to the sample bottles.

8) Analyze sample solutions by ICAP and/or GFAA. Use computer program to calculate final results. Analyze mercury on Pharmacia Mercury Monitor Model 100.

APPENDIX III

HEAVY METAL CONCENTRATION
AND PARTICLE SIZE DISTRIBUTION
OF INTERGRAVEL FINE SEDIMENTS FOR
BARBIE CREEK, YAKOUN RIVER, CANOE CREEK
AND FLORENCE CREEK

APPENDIX III

Heavy Metal Concentration and Particle Size Distribution of Intergravel Fine Sediments for : BARBIE 1 (82/09/15)

Metal *	Sample No. - Replication No. 1	2	3	4	5	Mean	S.D.
Hg **	.32	.35	.28	.33		.32	.03
As	33	25	28	32		30	4
Ba	159	123	106	119		127	23
Be	.3	.2	.3	.3		.3	.0
Cd	<.3	<.3	<.3	<.3		.3	.0
Co	14.8	14.7	13.2	17.3		15.0	1.7
Cr	98	79	157	189		131	51
Cu	35	24	21	27		27	6
Mn	944	655	660	1020		820	190
Ni	39	39	88	99		66	32
P	942	768	737	823		818	90
Pb	<3	4	<3	4		4	1
Sn	<2	2	<2	<2		2	0
Sr	61.9	55.8	44.5	52.5		53.7	7.3
V	73	67	71	77		72	4
Zn	91.3	81.8	80.3	82.2		83.9	5.0
Al	27900	26500	26900	28000		27325	741
Fe	33200	29300	31800	34000		32075	2061
Si	3130	3330	3260	4140		3465	458
Ca	4690	4850	4280	4720		4635	247
Mg	6740	6450	6140	6570		6475	253
Na	460	470	420	420		443	26

* ICAP, <0.15 mm fraction, as ug/g (ppm)
** Hg (Pharmacia Mercury Monitor)

Portion of total Sample (%)							
> .15 mm	75.2	79.4	84.3	79.3		79.6	3.7
< .15 mm	24.8	20.6	15.7	20.7		20.5	3.7

APPENDIX III

Heavy Metal Concentration and Particle Size Distribution of Intergravel Fine Sediments for : BARBIE 1
(83/02/22)

Metal *	Sample No. - Replication No. 1	2	3	4	5	Mean	S.D.
Hg **	.21	.21	.27	.28	.16	.23	.05
As	55	29	63	38	45	46	13
Ba	103	102	114	100	112	106	6
Be	.3	.2	.3	.4	<.2	.3	.1
Cd	<.3	<.3	<.3	<.3	<.3	.3	.0
Co	18.4	6.1	15.2	9.6	4.0	10.7	6.1
Cr	73	43	64	48	74	61	14
Cu	24	21	36	29	24	27	6
Mn	1940	1060	1630	950	648	1246	527
Ni	41	19	34	24	40	32	10
P	944	763	1030	1520	785	1008	307
Pb	4	<3	<3	<3	<3	3	0
Sn	<2	2	<2	<2	3	2	0
Sr	48.7	49.2	42.9	37.4	48.9	45.4	5.2
V	80	74	93	79	86	82	7
Zn	74.1	72.8	89.2	81.0	78.4	79.1	6.5
Al	27300	28600	33600	43200	30600	32660	6353
Fe	38400	31900	45100	33500	40200	37820	5308
Si	5060	5170	4630	5000	4940	4960	203
Ca	3870	3760	3550	2910	3530	3524	372
Mg	5280	5760	6040	4700	6430	5642	673
Na	340	350	350	310	320	334	18

* ICAP, <0.15 mm fraction, as ug/g (ppm)
** Hg (Pharmacia Mercury Monitor)

Portion of total Sample (%)							
$\geq$ .15 mm	86.8	86.8	89.5	83.4	92.5	87.8	3.4
$<$ .15 mm	13.2	13.2	10.5	16.6	7.5	12.2	3.4

APPENDIX III

Heavy Metal Concentration and Particle Size Distribution of Intergravel Fine Sediments for : BARBIE 2 (82/09/15)

Metal *	Sample No. - Replication No. 1	2	3	4	5	Mean	S.D.
Hg **	.33	.30	.31	.33		.32	.02
As	53	29	43	44		42	10
Ba	120	112	110	108		113	5
Be	.3	.2	.3	<.2		.3	.1
Cd	<.3	<.3	<.3	<.3		.3	.0
Co	11.6	11.9	14.1	13.4		12.8	1.2
Cr	42	59	60	59		55	9
Cu	20	22	23	26		23	3
Mn	381	425	406	412		406	18
Ni	19	30	33	33		29	7
P	842	825	827	845		835	10
Pb	3	3	<3	5		4	1
Sn	<2	<2	<2	4		3	1
Sr	44.0	46.9	43.7	44.9		44.9	1.4
V	65	66	68	67		67	1
Zn	74.1	81.0	79.9	84.1		79.8	4.2
Al	28100	28300	29600	28400		28600	678
Fe	29600	29600	29800	30200		29800	283
Si	3140	2940	3200	3660		3235	304
Ca	3550	3830	3540	3680		3650	136
Mg	5420	5560	5430	5440		5463	66
Na	420	470	430	480		450	29

* ICAP, <0.15 mm fraction, as ug/g (ppm)
** Hg (Pharmacia Mercury Monitor)

Portion of total Sample (%)							
≥ .15 mm	56.5	67.0	74.5	70.1		67.0	7.7
< .15 mm	43.5	33.0	25.5	29.9		33.0	7.7

APPENDIX III

Heavy Metal Concentration and Particle Size Distribution of Intergravel Fine Sediments for : BARBIE 2 (83/02/22)

Metal *	Sample No. - Replication No. 1	2	3	4	5	Mean	S.D.
Hg **	.34	.35	.32	.44	.37	.36	.05
As	69	69	50	80	46	63	14
Ba	121	110	118	118	144	122	13
Be	.2	.2	.3	.2	.2	.2	.0
Cd	<.3	<.3	<.3	<.3	<.3	.3	.0
Co	4.9	6.3	5.5	4.4	5.0	5.2	.7
Cr	39	36	45	49	58	45	8
Cu	35	28	28	27	32	30	4
Mn	690	656	572	530	569	603	67
Ni	20	18	23	30	32	25	6
P	1060	1050	907	1310	1220	1109	158
Pb	4	<3	4	5	3	4	1
Sn	3	<2	2	<2	3	2	1
Sr	47.2	45.8	44.7	45.7	67.0	50.1	9.5
V	78	72	85	80	90	81	7
Zn	83.5	81.5	84.4	78.3	95.4	84.6	6.5
Al	32500	30400	32700	31400	34600	32320	1574
Fe	37400	35500	35100	42800	40800	38320	3369
Si	5480	5660	4980	5600	5540	5452	272
Ca	2860	3010	2760	3250	4440	3264	683
Mg	5020	5070	5450	4930	6200	5334	523
Na	370	360	430	420	730	462	153

* ICAP, <0.15 mm fraction, as ug/g (ppm)
** Hg (Pharmacia Mercury Monitor)

Portion of total Sample (%)							
> .15 mm	70.3	69.9	79.2	67.6	85.1	74.4	7.4
< .15 mm	29.7	30.1	20.8	32.4	14.9	25.6	7.4

APPENDIX III

Heavy Metal Concentration and Particle Size Distribution of Intergravel Fine Sediments for : BARBIE 3
(82/09/15)

Metal *	Sample No. - Replication No. 1	2	3	4	5	Mean	S.D.
Hg **	.39	.47	.42	.60		.47	.09
As	62	57	59	71		62	6
Ba	194	184	183	207		192	11
Be	.4	.4	.4	.5		.4	.1
Cd	<.3	<.3	<.3	<.3		.3	.0
Co	31.9	26.6	25.3	43.7		31.9	8.4
Cr	56	62	51	53		55	5
Cu	21	25	21	22		22	2
Mn	1880	2040	2000	1830		1938	99
Ni	36	36	24	29		31	6
P	1170	1300	1300	1260		1257	61
Pb	<3	<3	<3	<3		3	0
Sn	<2	<2	3	4		3	1
Sr	91.5	89.5	83.7	87.4		88.0	3.3
V	92	88	86	94		90	4
Zn	131.0	126.0	129.0	135.0		130.2	3.8
Al	36900	33800	34800	36600		35525	1477
Fe	49800	47800	46600	50000		48550	1636
Si	3170	4050	3950	3780		3737	394
Ca	6100	6090	5800	5690		5920	207
Mg	8570	8000	8140	7950		8165	282
Na	630	550	550	580		578	38

* ICAP, <0.15 mm fraction, as ug/g (ppm)
** Hg (Pharmacia Mercury Monitor)

Portion of total Sample (%)							
> .15 mm	30.9	39.5	43.4	48.8		40.7	7.5
≤ .15 mm	69.1	60.5	56.6	51.2		59.4	7.5

APPENDIX III

Heavy Metal Concentration and Particle Size Distribution of Intergravel Fine Sediments for : BARBIE 3 (83/02/22)

Metal *	Sample No. - Replication No. 1	2	3	4	5	Mean	S.D.
Hg **	.32	.30	.27	.33	.37	.32	.04
As	34	40	34	47	55	42	9
Ba	181	186	214	191	224	199	19
Be	.4	.3	.3	.4	.4	.4	.1
Cd	<.3	<.3	<.3	<.3	<.3	.3	.0
Co	20.9	20.6	23.2	25.5	29.3	23.9	3.6
Cr	51	48	65	53	48	53	7
Cu	41	40	38	41	37	39	2
Mn	1720	1530	1560	1530	1050	1478	252
Ni	28	23	39	29	55	35	13
P	1100	1200	1060	1200	1250	1162	79
Pb	5	<3	4	6	5	5	1
Sn	3	3	5	3	3	3	1
Sr	86.7	78.3	117.0	80.0	72.8	87.0	17.5
V	108	104	100	107	105	105	3
Zn	129.0	125.0	126.0	127.0	128.0	127.0	1.6
Al	41000	38300	39800	39500	37700	39260	1297
Fe	48800	51400	48500	51100	56600	51280	3249
Si	4630	5600	5220	5600	5320	5274	398
Ca	5000	5030	5860	4790	4700	5076	460
Mg	8750	7920	9190	8020	7400	8256	710
Na	570	600	750	550	520	598	90

* ICAP, <0.15 mm fraction, as ug/g (ppm)
** Hg (Pharmacia Mercury Monitor)

Portion of total Sample (%)							
> .15 mm	58.6	24.0	58.4	56.0	51.9	49.8	14.7
< .15 mm	41.4	76.0	41.6	44.0	48.1	50.2	14.7

APPENDIX III

Heavy Metal Concentration and Particle Size Distribution of Intergravel Fine Sediments for : YAKOUN 1 (82/09/15)

Metal *	Sample No. - Replication No. 1	2	3	4	5	Mean	S.D.
Hg **	.18	.15	.23	.28		.21	.06
As	15	11	9	<8		11	3
Ba	197	191	203	196		197	5
Be	.4	.4	.5	.5		.5	.1
Cd	<.3	<.3	<.3	<.3		.3	.0
Co	16.4	15.0	18.3	15.6		16.3	1.4
Cr	64	58	69	61		63	4
Cu	30	28	40	34		33	5
Mn	1280	1160	1700	1770		1477	303
Ni	33	27	41	31		33	6
P	950	906	1060	1040		989	73
Pb	3	<3	<3	<3		3	0
Sn	5	2	2	4		3	1
Sr	103.0	102.0	103.0	102.0		102.5	.6
V	96	95	95	94		95	1
Zn	117.0	116.0	124.0	119.0		119.0	3.6
Al	35900	35000	35100	35100		35275	419
Fe	42600	42100	45900	45500		44025	1952
Si	3680	4740	4430	4450		4325	453
Ca	7860	7650	8060	7990		7890	180
Mg	9270	9320	9560	9530		9420	146
Na	770	720	720	740		738	24

* ICAP, <0.15 mm fraction, as ug/g (ppm)
** Hg (Pharmacia Mercury Monitor)

Portion of total Sample (%)							
> .15 mm	56.2	61.6	57.5	53.0		57.1	3.6
≤ .15 mm	43.8	38.4	42.5	47.0		42.9	3.6

APPENDIX III

Heavy Metal Concentration and Particle Size Distribution of Intergravel Fine Sediments for : YAKOUN 1 (83/02/22)

Metal *	Sample No. - Replication No. 1	2	3	4	5	Mean	S.D.
Hg **	.52	.32	.27	.23	.30	.33	.11
As	<8	<8	<8	<8	<8	8	0
Ba	201	208	208	202	193	202	6
Be	.4	.5	.4	.4	.4	.4	.0
Cd	<.3	<.3	<.3	<.3	<.3	.3	.0
Co	5.4	6.7	5.1	4.8	7.2	5.8	1.1
Cr	47	53	49	47	54	50	4
Cu	38	43	34	32	39	37	4
Mn	1310	2010	1250	1020	1350	1388	370
Ni	24	25	23	21	28	24	3
P	1030	1050	900	901	949	966	71
Pb	<3	5	<3	<3	<3	3	1
Sn	3	3	4	4	5	4	1
Sr	104.0	103.0	104.0	118.0	101.0	106.0	6.8
V	116	126	116	118	111	118	5
Zn	123.0	124.0	116.0	120.0	124.0	121.8	2.7
Al	43700	46100	44300	44000	41700	43960	1571
Fe	47300	47400	44300	43700	43600	45260	1927
Si	5320	5640	4780	6100	5380	5444	482
Ca	7840	7990	7680	7620	7370	7700	234
Mg	9970	10700	9720	10100	9570	10012	437
Na	630	660	690	840	630	690	87

* ICAP, <0.15 mm fraction, as ug/g (ppm)
** Hg (Pharmacia Mercury Monitor)

Portion of total Sample (%)							
$\geq$ .15 mm	56.9	60.4	78.9	61.1	70.7	65.6	9.0
$<$ .15 mm	43.1	39.6	21.1	38.9	29.3	34.4	9.0

APPENDIX III

Heavy Metal Concentration and Particle Size Distribution of Intergravel Fine Sediments for : YAKOUN 2 (82/09/15)

Metal *	Sample No. - Replication No. 1	2	3	4	5	Mean	S.D.
Hg **	.22	.21	.25	.16		.21	.04
As	16	<8	14	14		13	3
Ba	212	201	215	208		209	6
Be	.5	.5	.5	.4		.5	.1
Cd	<.3	<.3	<.3	<.3		.3	.0
Co	18.8	16.7	18.7	15.9		17.5	1.5
Cr	81	86	70	83		80	7
Cu	33	34	31	28		32	3
Mn	1260	1230	1950	1220		1415	357
Ni	43	40	36	45		41	4
P	915	940	960	929		936	19
Pb	<3	<3	<3	<3		3	0
Sn	3	3	3	4		3	0
Sr	121.0	89.3	98.6	97.5		101.6	13.6
V	101	99	96	97		98	2
Zn	126.0	118.0	118.0	120.0		120.5	3.8
Al	38200	35900	36600	36500		36800	983
Fe	43100	43400	43900	42500		43225	585
Si	2620	4310	4710	3590		3808	917
Ca	6970	6770	7000	6960		6925	105
Mg	9580	9430	8910	9220		9285	290
Na	730	700	680	730		710	24

* ICAP, <0.15 mm fraction, as ug/g (ppm)
** Hg (Pharmacia Mercury Monitor)

Portion of total Sample (%)							
> .15 mm	74.1	67.3	66.7	70.1		69.6	3.4
≤ .15 mm	25.9	32.7	33.3	29.9		30.5	3.4

APPENDIX III

Heavy Metal Concentration and Particle Size Distribution of Intergravel Fine Sediments for : YAKOUN 2 (83/02/22)

Metal *	Sample No. - Replication No. 1	2	3	4	5	Mean	S.D.
Hg **	.24	.22	.25	.30	.22	.25	.03
As	<8	<8	<8	<8	<8	8	0
Ba	203	211	204	204	226	210	10
Be	.4	.4	.4	.4	.4	.4	.0
Cd	<.3	<.3	<.3	<.3	<.3	.3	.0
Co	5.7	7.8	3.9	10.9	7.6	7.2	2.6
Cr	54	58	54	49	51	53	3
Cu	46	37	40	38	41	40	4
Mn	1490	1210	1390	1300	1250	1328	113
Ni	26	31	25	26	24	26	3
P	900	873	861	934	865	887	31
Pb	<3	<3	<3	<3	<3	3	0
Sn	5	3	4	4	5	4	1
Sr	97.3	99.8	97.3	100.0	105.0	99.9	3.1
V	109	108	106	112	117	110	4
Zn	127.0	125.0	122.0	125.0	127.0	125.2	2.0
Al	41800	42400	42200	43700	47400	43500	2293
Fe	43200	41600	41200	42400	42300	42140	773
Si	5220	5000	4670	5130	5230	5050	232
Ca	6440	6160	6360	6750	6590	6460	224
Mg	9410	9510	9220	9860	9880	9576	288
Na	570	670	630	650	660	636	40

* ICAP, <0.15 mm fraction, as ug/g (ppm)
** Hg (Pharmacia Mercury Monitor)

Portion of total Sample (%)							
> .15 mm	27.7	33.3	60.9	63.5	58.5	48.8	16.9
< .15 mm	72.3	66.7	39.1	36.5	41.5	51.2	16.9

APPENDIX III

Heavy Metal Concentration and Particle Size Distribution of Intergravel Fine Sediments for : CANOE 1 (82/09/15)

Metal *	Sample No. - Replication No. 1	2	3	4	5	Mean	S.D.
Hg **	.20	.21	.20	.22		.21	.01
As	8	<8	<8	16		10	4
Ba	79	77	80	81		79	2
Be	<.2	.2	<.2	.3		.2	.0
Cd	<.3	<.3	<.3	<.3		.3	.0
Co	10.1	14.4	19.1	12.9		14.1	3.8
Cr	63	73	51	47		58	12
Cu	13	18	14	18		16	3
Mn	1140	1580	1580	1260		1390	225
Ni	33	26	29	23		28	4
P	828	1230	919	1420		1099	274
Pb	<3	<3	3	<3		3	0
Sn	3	<2	<2	<2		2	1
Sr	43.7	44.9	45.4	46.6		45.2	1.2
V	71	86	77	93		82	10
Zn	65.0	60.8	65.2	62.5		63.4	2.1
Al	24100	27300	27800	28300		26875	1895
Fe	31200	37200	33800	41700		35975	4539
Si	4230	4590	4230	4550		4400	197
Ca	4210	4430	4550	4520		4428	154
Mg	5350	5000	5630	5070		5262	288
Na	650	620	700	610		645	40

* ICAP, <0.15 mm fraction, as ug/g (ppm)
** Hg (Pharmacia Mercury Monitor)

Portion of total Sample (%)							
> .15 mm	80.0	78.1	81.0	66.0		76.3	7.0
< .15 mm	20.0	21.9	19.0	34.0		23.7	7.0

APPENDIX III

Heavy Metal Concentration and Particle Size Distribution of Intergravel Fine Sediments for : CANOE 1 (83/02/22)

Metal *	Sample No. - Replication No. 1	2	3	4	5	Mean	S.D.
Hg **	.25	.29	.28	.29	.36	.29	.04
As	<7	<8	<8	<8	<8	8	0
Ba	133	95	107	90	96	104	17
Be	.2	<.2	<.2	<.2	.2	.2	.0
Cd	<.3	<.3	<.3	<.3	<.3	.3	.0
Co	7.0	2.9	4.5	2.1	1.9	3.7	2.1
Cr	46	52	59	44	42	49	7
Cu	20	41	37	22	22	28	10
Mn	307	361	465	415	365	383	60
Ni	23	24	28	24	24	25	2
P	933	1100	1270	1120	1460	1177	198
Pb	4	<3	<3	<3	<3	3	0
Sn	5	3	3	3	3	3	1
Sr	51.2	51.7	65.8	50.8	54.2	54.7	6.3
V	68	65	73	68	68	68	3
Zn	70.5	63.3	69.7	64.0	66.3	66.8	3.3
Al	31800	28300	30600	31900	33400	31200	1901
Fe	28700	26900	31800	25100	26700	27840	2555
Si	3800	5160	5220	4750	5490	4884	661
Ca	4960	4230	4660	4500	4950	4660	310
Mg	6210	4870	5410	5110	5350	5390	506
Na	910	640	630	730	720	726	112

* ICAP, <0.15 mm fraction, as ug/g (ppm)
** Hg (Pharmacia Mercury Monitor)

Portion of total Sample (%)							
$\geq$ .15 mm	77.9	81.2	79.9	87.4	83.8	82.0	3.7
$<$ .15 mm	22.1	18.8	20.1	12.6	16.2	18.0	3.7

APPENDIX III

Heavy Metal Concentration and Particle Size Distribution of Intergravel Fine Sediments for : FLORENCE 1 (82/09/15)

Metal *	Sample No. - Replication No. 1	2	3	4	5	Mean	S.D.
Hg **	.23	.25	.29	.16		.23	.05
As	<8	<8	<8	<8		8	0
Ba	112	120	98	95		106	12
Be	.3	.3	.3	.7		.4	.2
Cd	<.3	<.3	<.3	<.3		.3	.0
Co	37.9	41.9	20.7	16.4		29.2	12.6
Cr	41	60	77	69		62	15
Cu	26	20	27	16		22	5
Mn	1900	1780	2190	1140		1752	443
Ni	17	25	42	39		31	12
P	1340	1420	1330	1150		1310	114
Pb	<3	<3	<3	<3		3	0
Sn	3	4	6	6		5	2
Sr	68.9	71.5	64.3	60.1		66.2	5.0
V	110	107	105	98		105	5
Zn	80.3	84.5	83.6	85.6		83.5	2.3
Al	33800	32400	31600	33500		32825	1014
Fe	51100	54300	47200	43200		48950	4809
Si	3840	2980	2950	3390		3290	418
Ca	6450	6780	6420	6050		6425	298
Mg	5200	5500	5570	6080		5588	365
Na	840	960	1240	1110		1038	174

* ICAP, <0.15 mm fraction, as ug/g (ppm)
** Hg (Pharmacia Mercury Monitor)

Portion of total Sample (%)							
> .15 mm	55.6	61.8	66.1	73.8		64.3	7.6
< .15 mm	44.4	38.2	33.9	26.2		35.7	7.6

APPENDIX III

Heavy Metal Concentration and Particle Size Distribution of Intergravel Fine Sediments for : FLORENCE 1 (83/02/22)

Metal *	Sample No. - Replication No. 1	2	3	4	5	Mean	S.D.
Hg **	.24	.39	.32	.15	.13	.25	.11
As	<8	<8	<8	<8	<7	8	0
Ba	109	105	119	99	101	107	8
Be	.4	.4	.3	.3	.6	.4	.1
Cd	<.3	<.3	<.3	<.3	<.3	.3	.0
Co	13.3	6.5	39.6	8.3	7.1	15.0	14.0
Cr	60	44	49	49	35	47	9
Cu	26	30	19	19	16	22	6
Mn	1860	1460	1250	1700	1510	1556	234
Ni	36	25	29	23	12	25	9
P	1450	1700	2050	1750	1250	1640	305
Pb	<3	<3	<3	<3	<3	3	0
Sn	6	7	4	5	8	6	2
Sr	74.0	77.9	81.0	71.1	69.3	74.7	4.8
V	111	131	149	130	113	127	15
Zn	81.9	81.6	81.0	80.2	80.2	81.0	.8
Al	34900	33900	33800	31900	36400	34180	1648
Fe	50100	60800	75400	62200	47200	59140	11189
Si	4360	5260	4990	4940	3930	4696	539
Ca	6780	7380	7490	7140	6470	7052	424
Mg	5820	6010	5550	5990	6360	5946	296
Na	1330	1180	1040	1000	1060	1122	134

* ICAP, <0.15 mm fraction, as ug/g (ppm)
** Hg (Pharmacia Mercury Monitor)

Portion of total Sample (%)							
> .15 mm	59.1	75.2	62.8	65.4	82.9	69.1	9.8
< .15 mm	40.9	24.8	37.2	34.6	17.1	30.9	9.8

APPENDIX IV

HEAVY METAL CONCENTRATION
AND PARTICLE SIZE DISTRIBUTION OF
INTERGRAVEL FINE SEDIMENTS FOR COWICHAN RIVER,
FOXY CREEK, LEMIEUX CREEK, MAMIN RIVER, MYRA CREEK,
PINCHI CREEK, QUINSAM RIVER, SALMON RIVER AND SEYMOUR RIVER

APPENDIX III

Heavy Metal Concentration and Particle Size Distribution of Intergravel Fine Sediments for : COWICHAN RIVER (83/07/27)

Metal *	Sample No. - Replication No. 1	2	3	4	5	Mean	S.D.
Hg **	.17	.19	.16	.18		.18	.01
As	<7	11	<8	8		9	2
Ba	100	107	98	100		101	4
Be	.6	.6	.6	.6		.6	.0
Cd	1.1	1.1	1.1			1.1	.0
Co	24.9	21.4	27.1	22.0		23.9	2.7
Cr	64	68	58	58		62	5
Cu	70	72	68	68		69	2
Mn	998	1150	1000	1030		1044	72
Ni	35	34	29	28		32	4
P	1120	1230	1140	1180		1167	49
Pb	11	12	10	9		10	1
Sn	11	11	10	10		10	1
Sr	97.6	97.5	98.5	100.0		98.4	1.2
V	150	152	159	155		154	4
Zn	85.9	89.2	88.9	89.4		88.3	1.6
Al	31000	31600	31500	31700		31450	311
Fe	42900	44000	45200	43800		43975	946
Si	4360	4270	3800	4780		4303	402
Ca	13800	14000	14000	14300		14025	206
Mg	14700	14700	14700	14700		14700	0
Na	580	610	600	600		597	13

* ICAP, <0.15 mm fraction, as ug/g (ppm)
** Hg (Pharmacia Mercury Monitor)

Portion of total Sample (%)							
≥ .15 mm							
< .15 mm							

APPENDIX III

Heavy Metal Concentration and Particle Size Distribution of Intergravel Fine Sediments for : FOXY CREEK (83/07/18)

Metal *	Sample No. - Replication No. 1	2	3	4	5	Mean	S.D.
Hg **	.17	.19	.20	.20		.19	.01
As	25	25	31	25		27	3
Ba	498	556	628	492		543	63
Be	.6	.8	.7	.5		.7	.1
Cd	1.1	1.0	.9	1.1		1.0	.1
Co	17.6	16.4	17.7	21.5		18.3	2.2
Cr	86	83	66	57		73	14
Cu	62	56	57	58		58	2
Mn	1620	1600	1780	1980		1745	176
Ni	50	50	41	37		44	7
P	2010	2230	2230	2100		2142	108
Pb	12	12	14	13		13	1
Sn	4	4	5	3		4	1
Sr	144.0	178.0	188.0	173.0		170.8	18.9
V	125	128	115	106		118	10
Zn	157.0	153.0	156.0	160.0		156.5	2.9
Al	29400	33300	29000	24500		29050	3600
Fe	50000	50600	45000	36900		45625	6335
Si	3680	2880	3850	3830		3560	460
Ca	15600	13100	11000	9970		12417	2490
Mg	7590	8650	8260	7380		7970	589
Na	850	860	860	890		865	17

* ICAP, <0.15 mm fraction, as ug/g (ppm)
** Hg (Pharmacia Mercury Monitor)

Portion of total Sample (%)							
$\geq$ .15 mm							
$\overline{<}$ .15 mm							

APPENDIX III

Heavy Metal Concentration and Particle Size Distribution of Intergravel Fine Sediments for : LEMIEUX CREEK (83/10/10)

Metal *	Sample No. - Replication No. 1	2	3	4	5	Mean	S.D.
Hg **	.05	.05	.05	.05		.05	.00
As	27	24	26	23		25	2
Ba	128	139	123	126		129	7
Be	.3	.3	.3	.3		.3	.0
Cd	2.6	2.7	2.4	2.3		2.5	.2
Co	17.3	17.7	17.5	16.3		17.2	.6
Cr	90	90	92	88		90	2
Cu	48	51	50	48		49	1
Mn	763	773	726	708		743	31
Ni	62	62	62	59		61	1
P	1890	1960	1950	1920		1930	32
Pb	13	14	12	11		13	1
Sn	<2	<2	<2	<2		2	0
Sr	116.0	122.0	117.0	125.0		120.0	4.2
V	100	104	100	101		101	2
Zn	163.0	168.0	163.0	162.0		164.0	2.7
Al	22500	23600	22800	22600		22875	499
Fe	35500	35900	36100	35500		35750	300
Si	1900	2180	3200	2650		2483	570
Ca	28400	29300	29300	31600		29650	1367
Mg	9730	10300	10300	10100		10107	269
Na	500	540	480	480		500	26

* ICAP, <0.15 mm fraction, as ug/g (ppm)
** Hg (Pharmacia Mercury Monitor)

Portion of total Sample (%)							
> .15 mm	73.0	73.0	70.0	72.0		72.0	1.4
< .15 mm	27.0	27.0	30.0	28.0		28.0	1.4

APPENDIX III

Heavy Metal Concentration and Particle Size Distribution of Intergravel Fine Sediments for : MAMIN RIVER (83/11/03)

Metal *	Sample No. - Replication No. 1	2	3	4	5	Mean	S.D.
Hg **	.22	.21	.17	.20	.29	.22	.04
As	<8	9	<8	<8	<8	8	0
Ba	98	110	108	108	113	107	6
Be	.3	.4	.3	.3	.5	.4	.1
Cd	1.0	1.0	1.0	1.0	1.2	1.0	.1
Co	20.2	17.2	15.6	19.7	18.0	18.1	1.9
Cr	79	68	70	71	82	74	6
Cu	38	36	29	27	34	33	5
Mn	1440	1570	1220	1260	1320	1362	143
Ni	65	37	37	39	47	45	12
P	1180	1270	1030	1130	1320	1186	115
Pb	6	7	<3	<3	8	5	2
Sn	8	5	9	6	6	7	2
Sr	109.0	102.0	108.0	140.0	124.0	116.6	15.4
V	99	112	102	105	109	105	5
Zn	103.0	106.0	97.6	92.1	96.8	99.1	5.5
Al	40000	38700	34200	38000	38800	37940	2211
Fe	48100	51900	42500	45300	53700	48300	4604
Si	1750	890	1930	1160	1870	1520	466
Ca	13000	11500	10600	12100	11700	11780	876
Mg	16800	11400	10700	12600	12400	12780	2375
Na	2600	2080	2050	2370	2050	2230	247

* ICAP, <0.15 mm fraction, as ug/g (ppm)
** Hg (Pharmacia Mercury Monitor)

Portion of total Sample (%)							
≥ .15 mm	62.0	56.0	74.0	50.0	66.0	61.6	9.2
< .15 mm	38.0	44.0	26.0	50.0	43.0	40.2	9.0

APPENDIX III

Heavy Metal Concentration and Particle Size Distribution of Intergravel Fine Sediments for : MYRA CREEK (83/03/18)

Metal *	Sample No. - Replication No. 1	2	3	4	5	Mean	S.D.
Hg **	.64	.35	.34			.44	.17
As	<40	24	29			31	8
Ba	100	133	152			128	26
Be	<.8	<.2	.4			.5	.3
Cd	<2.0	.7	.7			1.1	.8
Co	21.0	14.4	15.6			17.0	3.5
Cr	91	42	81			71	26
Cu	73	71	79			74	4
Mn	921	708	1040			890	168
Ni	50	19	38			36	16
P	530	515	603			549	47
Pb	<20	19	19			19	1
Sn	<8	3	2			4	3
Sr	46.7	40.6	43.7			43.7	3.1
V	84	77	97			86	10
Zn	93.0	125.0	148.0			122.0	27.6
Al	24900	29000	34200			29367	4661
Fe	26200	25600	32400			28067	3765
Si	13300	4650	3580			7177	5330
Ca	9460	9930	9690			9693	235
Mg	7580	8350	9490			8473	961
Na	7000	350	370			2573	3834

* ICAP, <0.15 mm fraction, as ug/g (ppm)
** Hg (Pharmacia Mercury Monitor)

Portion of total Sample (%)							
≥ .15 mm	79.0	61.0	58.0			66.0	11.4
< .15 mm	21.0	39.0	42.0			34.0	11.4

APPENDIX III

Heavy Metal Concentration and Particle Size Distribution of Intergravel Fine Sediments for : PINCHI CREEK (83/07/20)

Metal *	Sample No. - Replication No. 1	2	3	4	5	Mean	S.D.
Hg **	.19	.17	.16	.25		.19	.04
As	<8	10	<8	<8		9	1
Ba	307	277	271	213		267	39
Be	<.2	<.2	<.2	<.2		.2	.0
Cd	.6	.5	.5	.7		.6	.1
Co	13.2	16.0	12.2	19.6		15.3	3.3
Cr	113	143	130	83		117	26
Cu	33	31	28	29		30	2
Mn	578	665	517	457		554	89
Ni	71	82	66	60		70	9
P	823	1000	814	788		856	97
Pb	7	9	7	10		8	1
Sn	<2	3	4	<2		3	1
Sr	55.3	60.4	55.9	52.4		56.0	3.3
V	74	90	85	68		79	10
Zn	71.9	79.6	68.8	65.7		71.5	6.0
Al	16200	16900	15700	15900		16175	525
Fe	28100	31000	29600	25200		28475	2484
Si	3860	2760	3600	4950		3792	903
Ca	10100	10100	9370	8100		9418	943
Mg	11600	10800	10500	9760		10665	761
Na	390	440	370	370		392	33

* ICAP, <0.15 mm fraction, as ug/g (ppm)
** Hg (Pharmacia Mercury Monitor)

Portion of total Sample (%)							
$\geq$ .15 mm							
$\overline{<}$ .15 mm							

APPENDIX III

Heavy Metal Concentration and Particle Size Distribution of Intergravel Fine Sediments for : QUINSAM R Q1 (83/06/22)

Metal *	Sample No. - Replication No. 1	2	3	4	5	Mean	S.D.
Hg **	.13	.11	.15	.09		.12	.03
As	<8	<8	<8	<8		8	0
Ba	75	69	69	85		75	8
Be	.3	.3	.4	<.2		.3	.1
Cd	.5	.7	.5	.7		.6	.1
Co	13.1	15.3	13.0	14.4		14.0	1.1
Cr	65	46	66	87		66	17
Cu	83	84	85	93		86	5
Mn	1210	944	1360	894		1102	221
Ni	32	23	32	47		33	10
P	639	572	662	647		630	40
Pb	5	4	7	<3		5	2
Sn	6	10	8	7		8	2
Sr	66.8	66.0	61.2	77.7		67.9	7.0
V	134	131	122	132		130	5
Zn	62.5	57.3	66.6	63.4		62.5	3.9
Al	29400	28800	28800	34300		30325	2665
Fe	47000	41800	50400	36200		43850	6206
Si	4110	4360	3930	4390		4197	218
Ca	26000	23700	30200	19000		24725	4670
Mg	6600	6890	6540	8240		7068	796
Na	730	790	700	930		788	102

* ICAP, <0.15 mm fraction, as ug/g (ppm)
** Hg (Pharmacia Mercury Monitor)

Portion of total Sample (%)							
> .15 mm	77.0	83.0	74.0	71.0		76.3	5.1
< .15 mm	23.0	17.0	26.0	29.0		23.8	5.1

APPENDIX III

Heavy Metal Concentration and Particle Size Distribution of Intergravel Fine Sediments for : QUINSAM R Q2 (83/06/22)

Metal *	Sample No. - Replication No. 1	2	3	4	5	Mean	S.D.
Hg **	.28	.24	.16	.15		.21	.06
As	9	<8	<8	11		9	1
Ba	122	121	83	89		104	20
Be	.2	.3	.4	.3		.3	.1
Cd	.7	.6	.6	.5		.6	.1
Co	13.5	13.7	12.5	10.4		12.5	1.5
Cr	52	67	47	55		55	9
Cu	67	64	81	79		73	9
Mn	1970	1870	1070	2150		1765	478
Ni	24	28	19	21		23	4
P	763	712	881	896		813	90
Pb	17	15	8	5		11	6
Sn	5	3	7	7		6	2
Sr	112.0	117.0	70.1	67.7		91.7	26.4
V	114	130	127	134		126	9
Zn	97.5	103.0	73.6	71.5		86.4	16.2
Al	37600	36000	36600	34500		36175	1297
Fe	35300	38400	35000	37700		36600	1703
Si	7950	7240	4760	5380		6333	1508
Ca	17100	17300	13200	13000		15150	2370
Mg	8730	9000	7190	7010		7982	1028
Na	500	460	480	510		486	22

* ICAP, <0.15 mm fraction, as ug/g (ppm)
** Hg (Pharmacia Mercury Monitor)

Portion of total Sample (%)							
> .15 mm	64.0	63.0	47.0	26.0		50.0	17.8
< .15 mm	36.0	37.0	53.0	74.0		50.0	17.8

APPENDIX III

Heavy Metal Concentration and Particle Size Distribution of Intergravel Fine Sediments for : SALMON RIVER (83/08/10)

Metal *	Sample No. - Replication No. 1	2	3	4	5	Mean	S.D.
Hg **	.07	.07	.10			.08	.02
As	<8	<8	9			8	1
Ba	116	109	94			106	11
Be	<.2	<.2	<.2			.2	.0
Cd	.7	.6	.4			.6	.2
Co	10.8	10.6	4.3			8.6	3.7
Cr	56	59	45			53	8
Cu	25	22	21			23	2
Mn	722	935	637			765	154
Ni	33	35	23			30	6
P	1140	986	859			995	141
Pb	4	5	<3			4	1
Sn	5	3	3			4	1
Sr	56.2	51.7	49.7			52.5	3.3
V	69	65	65			66	2
Zn	118.0	112.0	73.3			101.1	24.3
Al	24000	21500	20800			22100	1682
Fe	23600	23700	21600			22967	1185
Si	4530	4320	5020			4623	359
Ca	11300	10700	6860			9620	2409
Mg	7260	6600	6460			6773	427
Na	620	540	530			563	49

* ICAP, <0.15 mm fraction, as ug/g (ppm)
** Hg (Pharmacia Mercury Monitor)

Portion of total Sample (%)							
> .15 mm	59.0	80.0	77.0			72.0	11.4
≤ .15 mm	41.0	20.0	23.0			28.0	11.4

APPENDIX III

Heavy Metal Concentration and Particle Size Distribution of Intergravel Fine Sediments for : SEYMOUR RIVER (83/08/10)

Metal *	Sample No. - Replication No. 1	2	3	4	5	Mean	S.D.
Hg **	.06	.05	.04			.05	.01
As	<8	<8				8	0
Ba	87	83	57			75	17
Be	<.2	<.2	<.2			.2	.0
Cd	.7	.5	.3			.5	.2
Co	12.0	7.3	11.3			10.2	2.5
Cr	25	31	30			29	3
Cu	40	29	25			32	8
Mn	729	633	450			604	142
Ni	9	8	3			7	3
P	671	662	582			638	49
Pb	15	7	5			9	5
Sn	4	4	<2			3	1
Sr	58.0	67.6	56.4			60.7	6.1
V	84	102	126			104	21
Zn	79.2	68.4	61.8			69.8	8.8
Al	20100	20100	15500			18567	2656
Fe	28500	31900	36600			32333	4067
Si	4520	4220	4100			4280	216
Ca	8290	9380	8160			8610	670
Mg	7270	7010	5370			6550	1030
Na	1020	1160	900			1027	130

* ICAP, <0.15 mm fraction, as ug/g (ppm)
** Hg (Pharmacia Mercury Monitor)

Portion of total Sample (%)							
> .15 mm	69.0	74.0	89.0			77.3	10.4
< .15 mm	31.0	26.0	11.0			22.7	10.4

APPENDIX V

1981 AND 1982
FREEZE CORE AND SEDIMENT TRAP SAMPLES
COLLECTED AT BARBIE CREEK-3

APPENDIX V 1981 AND 1982 FREEZE CORE AND SEDIMENT TRAP SAMPLES COLLECTED AT BARBIE CREEK-3

METAL (ug/g)	SEPTEMBER 10, 1981																MARCH 11, 1982				
	FREEZE CORE								SEDIMENT TRAP*								FREEZE CORE				
	1	2	3	4	5	6	$\bar{x}$	(S.D.)	1	2	3	4	5	6	$\bar{x}$	(S.D.)	1	2	3	$\bar{x}$	(S.D.)
Hg	.27	.23	.19	.22	.34	.21	.24	(.05)	.30	.20	.23	.32	.35	.29	.28	(.05)	.42	.53	.62	.52	(.10)
As	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	102	138	130	123	(19)
Al	33900	37600	33700	35300	34800	37800	35400	(1870)	31900	31000	30900	32600	32500	33100	32000	(900)	31300	28500	30400	30100	(1430)
Fe	63500	60800	60600	67400	72800	52800	63000	(6790)	62500	63900	63900	63400	64100	58300	62700	(2220)	73100	71100	72500	72200	(1030)

Hg analysis by flameless atomic absorption spectrophotometry, other metals by ICAP

*after 77 day exposure, 10 cm diameter by 26 cm high acid washed polyethylene container filled with 1.4 cm diameter acid washed marbles